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New Process Manufacture of High-Duty Cast Iron

Considerable development has been effected in recent years in the improvement of the strength, toughness, resistance to shock, texture, and degasification of high-duty cast iron. Several processes for the improvement and refining of pig iron are in operation, but, after considerable research and investigation, Sir W. G. Armstrong Whitworth and Co., Ltd., have installed several rotary-type melting furnaces at their Close Works, Gateshead, which enables them to produce special high-duty iron of the highest class. This installation, together with data relating to the refined iron manufactured, are discussed in the article.

THE present-day demand for higher duties in cast iron to enable it to hold its place and increase its sphere of usefulness in industry has led to much research work on the metal itself.

In the course of such work it has been found that several fundamental factors were underlying the change from the old accepted quality of cast iron to the modern product; a change which has placed cast iron in its rightful place, and enabled its inclusion in design where only steel was formerly considered.

A complete description of one of these melting units was given in METALLURGIA in April, 1931, but it will be of interest to gain some idea of the description and working of this plant.

The furnace body consists of a steel shell mounted on two tracks, which run on oscillating rollers. The body is lined with a rammed acid or basic lining, about 14½ in. thick, and is rotated by means of a motor, gearbox, and chain drive. This rotation gear is also arranged so that a very slow motion is used for tapping purposes. At the

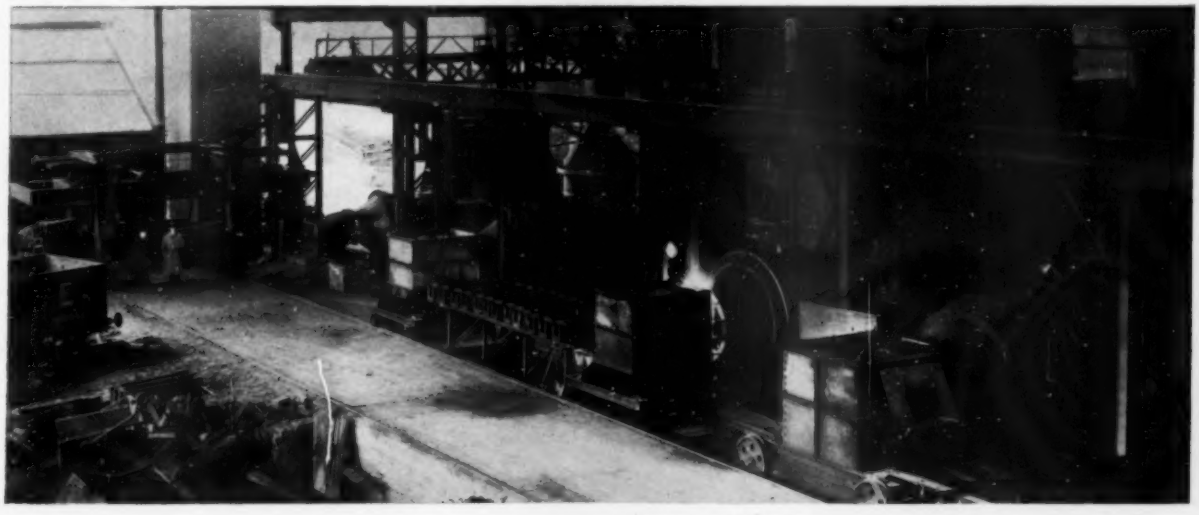


Fig. 1.—Group of Sesci Furnaces installed at the Works of Messrs. Armstrong, Whitworth (Ironfounders) Limited.

Research indicated the electric furnace for manufacturing such an iron, but it was found similarly advantageous results could be obtained from the rotary air furnace, fired by pulverised coal, without the expensive running costs that are attached to electric melting.

This research led to the installation of a pulverised coal-fired rotary air furnace, of a melting capacity of 5 tons, at Close Works in December, 1930. At later dates a 2-ton, 10-ton, and a further 5-ton units have been added; that now makes this plant one of the finest melting batteries in Europe, or America, for cast iron.

combustion end of the furnace is fitted a special burner, which, in this type, is specially designed for the combustion of anthracite or semi-anthracite fuel. The opposite end of the furnace is connected by a movable head to the flues. The products of combustion are led first to the recuperator and then to the chimney.

The air supply is provided by a Root's-type blower, which delivers a constant volume of air for a constant speed. This air is then carried through a recuperator and preheated, according to the progress of the melt, up to 600° C. It then passes under the coal hoppers, where it

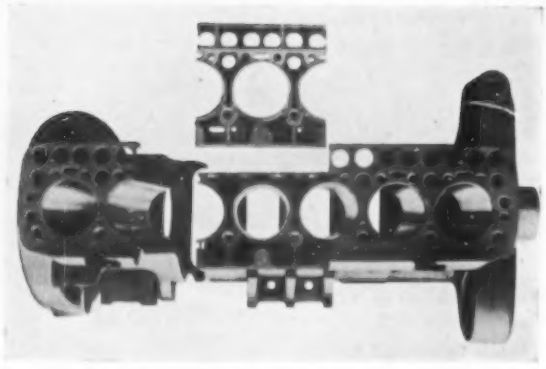


Fig. 2.—Automobile cylinder block.

receives the coal, which, in turn, is measured out by positive screw feeders and then to the furnace. At the point where the pipe line joins the furnace a rotary airtight joint is fitted which prevents any loss of the carefully measured-out air and coal. As the motors for the blower and coal feeders are variable-speed type, any quantity of air and fuel can be delivered at once at the will of the operator. An important point about this type of furnace is that all the air entering the furnace is directly controlled, thus permitting accurate control of flame and atmosphere.

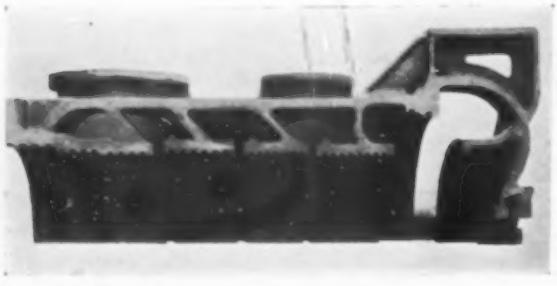
The intense heat in the furnace lining is transmitted during rotation directly to the metal bath by actual contact, thus overcoming the heat-insulating power of the slag, which, however, protects the metal from contamination by gases. The heat, as pointed out, is generated by the burning of pulverised coal on a refractory lath-type grid situated in the combustion chamber, somewhat on the principle of a bunsen burner with its gauze flame carrier.

The coal is carried in and burned by means of an air supply raised to a suitable temperature in a regenerator situated in the exhaust flues and driven forward by the blower. The coal, except for that used in the initial lighting-up, is anthracite, and can be obtained from any suitable coal measure, typical analyses of such already having been given. Since the main feature is to concentrate the absorption of heat into the bath of metal, it is necessary to control the combustion of the coal—that is, the flame—at a position predetermined in the design of the furnace. This position is immediately in front of the grid in the combustion chamber.

From this description it will be seen that the rotary furnace provides conditions for producing metal not only free from the effects of contamination necessarily associated with cupola practice, but one of a predetermined composition, and of a range hitherto not economically possible. The cupola, with its circumscribed heat range and direct contact between descending metal and ascending gases, has largely controlled and limited the composition and structure of cast iron produced therefrom.

It has long been recognised that vastly different structures could be obtained with the same composition if only means of production were available economically and conveniently to provide a suitable range of the necessary conditions. In the many investigations into this new field of the structure of cast iron, in which the British Cast Iron Research Association has rendered invaluable service, it was early established that superheating of the metal, and the amount and nature of carbon present, were the most prominent factors.

Fig. 3.—Turbine cylinder cut up in order to reveal any defects.



The effect of superheating cast iron is to produce in the final solid material an iron wherein the graphite is in a very fine, evenly disseminated condition in a matrix of pearlite or ferrite, depending on the degree and length of time of such superheat. Such a structure, in addition to thus embodying the softer components of the iron, if required, has the added interest and value of exhibiting a lower shrinkage and a more even grain-size for different metal thicknesses, a property hitherto attainable only by alloy additions of special processes. The theory underlying this fine graphite formation is generally ascribed to the more complete solution of the original flake graphite in the materials employed, with the consequent removal or reduction in size of graphite "nuclei," which would induce and form the starting-point of larger flake graphite.

Some scientific evidence is, however, hereby shown for the use in most cupola charges of "scrap," which, whilst introducing a serious unknown factor into the calculation, is of finer graphite form than "pig," due to its having been twice melted. The extent to which superheating should be carried out depends on the duties to be demanded of the castings produced from the metal, the proportion of pearlite retained being the main underlying factor.

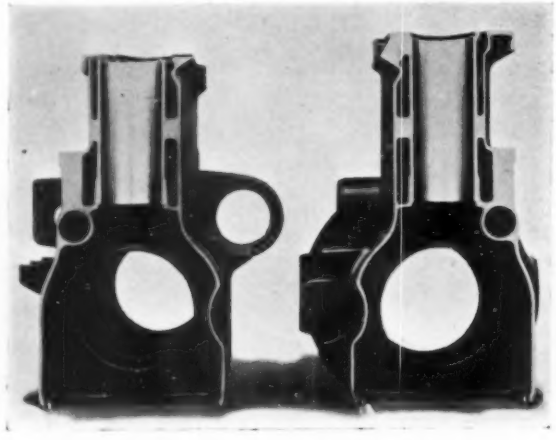


Fig. 4.—Automobile cylinder block.

It was further known that a more complete control of total carbon in pig iron facilitated the production of a desired structure.

The use of steel in the cupola charge, even under limited control, is one evidence of the value of lower carbon towards improved structure. Low total-carbon cast iron, in addition to producing fine graphite, also produces a finer grain structure which, as one would expect, and as shown, is responsible for great increase in strength.

The new process of rotary melting has, therefore, provided a means of embodying the factors necessary to bridge the gap between grey cast iron and malleable cast iron, and, by superimposing the malleable process thereon, of attaining strengths usually only attributed to steel.

Similarly, for special-duty conditions, alloy cast iron of any desired composition can be made, either as a complete and separate melt, where quantities warrant it, or by adding the alloying element, including carbon, in a residual furnace bath or in the ladle. Another feature of superheated iron which is worthy of note is the less effect thereon of the elements usually present in cast iron, such

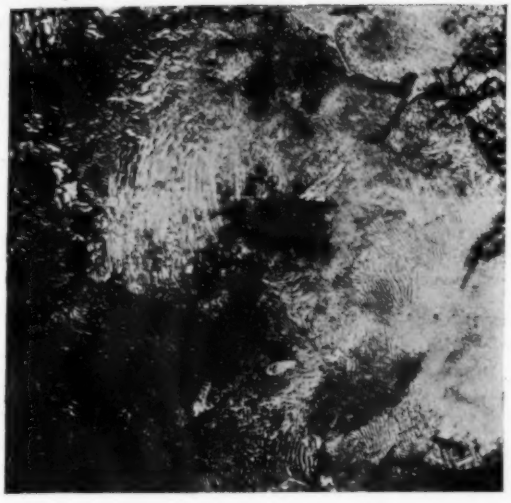


Fig. 5.—Cylinder iron × 650.

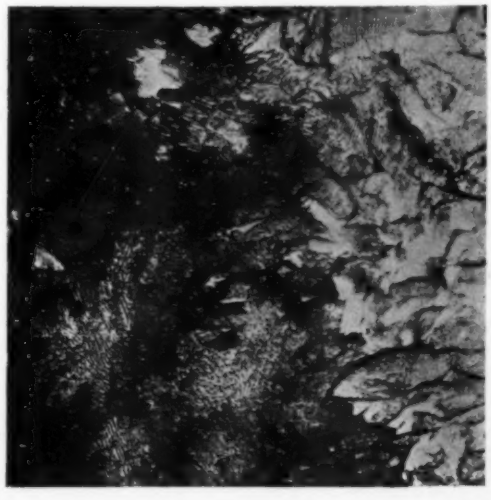
as silicon, manganese and phosphorus, so that a wider range of castings can be produced from the same composition, an advantage to be considered in many foundries at the present time. In the form of pig iron, whether of alloy composition or not, a ready means of producing fine-grain cast iron from the cupola is thus rendered available.

With the wider range of composition available some modification of existing test-pieces became necessary, and it is interesting to record one introduced to measure the fluidity of the metal. This was designed by Sipp, in Germany, and is of the degree shown in Figs. 8 and 9; from which it will be seen that the test-piece is run under standard conditions, so that all measurements are comparative.

Structures embodying a highly pearlitic structure, with fine graphite disseminated throughout, are seen in Figs. 5 and 6. These were taken from a motor-cylinder block, where resistance to wear was essential. Fig. 2 shows one of these blocks with material thicknesses varying from $\frac{3}{16}$ in. to $\frac{5}{8}$ in. The casting includes 6-cylinder bores, crankcase, valve chambers, timing gear, etc., all in one casting, and is being manufactured in large numbers without any recourse to chills or denseners. The analysis of the metal in these castings is as follows:—T.C., 2.9; Si., 2.5 to 3; Mn., 0.7; S., 0.06; P., 0.35 per cent.

The tensile tests taken from these castings range from 18 to 20 tons per sq. in. In one case a test was taken with a standard repeated-impact machine, and the test-piece stood 2,234 blows before fracture. This casting is close grained in varying sections and easily machined.

Fig. 6.—Cylinder iron × 650.



For medium-range castings, with thicknesses from 1 in. to 2 in., the example shown in Fig. 3 is a turbine cylinder. This turbine cylinder was noted for its difficulty when issued for previous orders, and it was with a view to testing out the value of rotary-furnace iron that one of these was made expressly to be machined and cut up.

It shows the turbine piece after machining, with the cut section facing the camera. Every one of the sections where two walls met was perfectly sound. No special feeding heads were required; in fact, the casting turned the scale at 4 tons 4 cwts., and the metal was produced in a 5-ton furnace. This proves the fact that no intricate system of feeding heads could have been used. The analysis was as follows:—T.C., 3; Si., 1.36; Mn., 0.79; S., 0.078; and P., 0.46%.

The details of the test figures are shown in Table I.

TABLE I.

MATERIAL TESTS ON EXPERIMENTAL H.P. TURBINE CYLINDER.

Tensile: On $\frac{1}{2}$-in. square test-bar, 19·0—19·2 tons per sq. in.

Transverse Test:

Size of Bar. In.	Tons.	Deflection. In.
36 × 2 × 1 ..	1·84 ..	0·46
12 × 2 × 1 ..	6·44 ..	0·13
12 × 1 × 1 ..	1·72 ..	0·12
18 × 1·2 dia. ..	1·80 ..	0·28

Drop Test: 1·0 $\frac{5}{8}$ in. square bar, 6.0 $\frac{1}{4}$ in. centres, 40 lb. at 22·95 in. drop.

Compression Test: 73 and 72 tons per sq. in.

Repeated Impact: 1,354 blows with $1\frac{1}{2}$-in. drop.

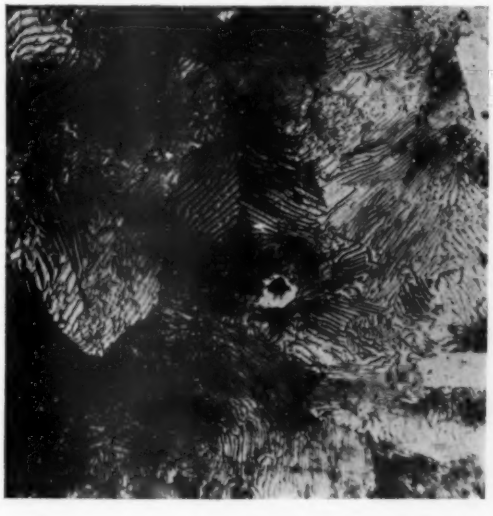


Fig. 7.—Cylinder iron, mainly pearlitic × 650.

Since the above experiment was carried out about 20 different turbine pieces have been made in the same manner, and test-pieces have been taken up to 22 tons per sq. in. These castings have been entirely satisfactory under machining and water test.

The third and last example is the thickest job which the author has encountered. This is a machined body, with the industrial purpose of which the author is not familiar. It has varying sections from 2 in. up to 12 in. thick. The minimum tensile under which the casting would be accepted was 18 tons, and it was, therefore, a clear case for rotary-furnace production. No further details are available regarding the behaviour of this casting in the machine shop. The analysis was as follows:—T.C., 2.7; Si., 1.3; Mn., 0.7; S., 0.067; and P., 0.25%. The tensile test was returned at 19.6 tons per sq. in., and the weight 5 tons 10 cwts. These three castings, it is thought, are sufficient to prove that the rotary furnace is not confined to either very thin castings, or, on the other hand, very thick, but

the benefits of the furnace can be fully realised on any class of grey-iron work. The test figures quoted are not laboratory experiments, but are actual commercial castings made in the usual way. Such castings as these shown are being made daily.

Advantages of "New Process" Pig Iron.

"New Process" melting lends itself to the production of an iron of low-carbon content, wherein the graphite is in an extremely fine, well-disseminated condition. These advantages have been found of tremendous importance, as it allows a pig iron to be produced of a low-carbon content that offsets the carbon pick-up, and the addition of other high-carbon irons during cupola melting. Furthermore, the graphite being extremely fine it does not present a large nuclei for graphitisation. The control of the

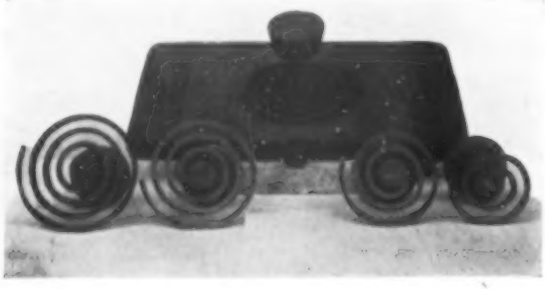


Fig. 8.—Fluidity test-pieces and pattern.

furnace ensures perfect non-oxidising conditions, giving an iron that casts freely and ensures freedom from oxide inclusions in the finished casting.

It will be readily understood that low-carbon pig iron, wherein the graphite is extremely fine, is very advantageous in producing castings of uniform grain both in thick and thin sections.

Allied with its freedom from porosity "New Process" iron sets a new standard in strength, close texture, and resistance to wear never previously associated with cast iron. In castings where machining has been essential in $\frac{3}{16}$ in. thicknesses, tensile strengths have been obtained up to 24 tons per sq. in. Illustration 7 shows a photo-micrograph of this iron at 650 diameters; it will be noted

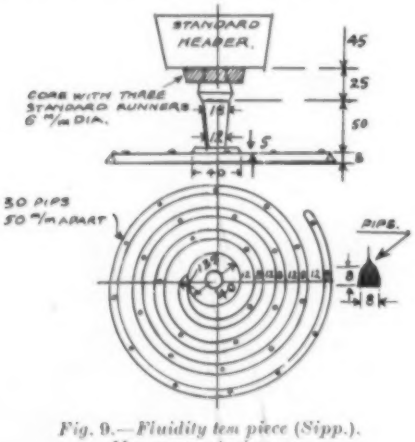


Fig. 9.—Fluidity test piece (Sipp.). Measurements in mm.

that the graphite is in a nodular or fine curly condition, in a matrix of fine pearlite, free from ferrite or cementite.

"New Process" Pig Iron for Malleable Castings.

Similarly advantageous results are obtained by using pig iron manufactured by this new process for malleable castings. It will be readily understood that a low-carbon iron allows a higher silicon content to be used, ensuring a saving in annealing time and a finished malleable of greatly improved physical characteristics. Allied to this are the advantages of a lower sulphur content than usually associated with malleable iron, a perfectly degasified non-oxidised iron, with a range of analyses to meet requirements of all types of malleable work.

It will be of interest to those associated with the foundry trade that plant is now being installed for producing pig iron by machine casting in semi-permanent moulds. This will give an extremely clean well-shaped pig, free from sand, easily handled owing to its freedom from rough edges, yet will still retain the fracture associated with sand casting. This is an innovation in the iron industry, and Close Works are to be congratulated on designing and developing this plant.

It is hoped that the foregoing remarks will have interested the reader in what is undoubtedly an important milestone in the progress of the foundry industry. Sir W. G. Armstrong, Whitworth and Co. will gladly give further particulars of their process and products, and all foundries interested in the manufacture of good-class iron castings should write for their brochure No. 518.

NEW SPECIFICATIONS.

British Standard Screws.

THE British Standards Institution have already issued standards for British Standard Whitworth (B.S.W.), British Standard Fine (B.S.F.), and British Association (B.A.) threads. Standard specifications have also been prepared from time to time for bolts and nuts made with these threads, and of these the following are the principal:—

- B.S.S. No. 190, B.S.W. bright hexagon bolts, setscrews, and nuts, split-pins, washers, and studs.
- B.S.S. No. 191, B.S. fine bright hexagon bolts, setscrews, and nuts, split-pins, washers, and studs.
- B.S.S. No. 193, British Standard Whitworth (small hexagon), (B.S.W.S.) bright hexagon bolts, nuts, and setscrews, split-pins, washers, and studs.
- B.S.S. No. 325, black iron and steel, cup and countersunk bolt-heads, nuts, and washers.
- B.S.S. No. 28, black bolts and nuts.

Any developments or additions to this list will naturally be of universal interest to industry, and the extension of the above list to provide for bright countersunk round and cheese-head screws, B.S.S. No. 450, and bright square-head setscrews, B.S.S. No. 451, will, therefore, be a matter of importance to all engineering firms. The specifications provide for round, countersunk, and cheese-head screws from $\frac{1}{8}$ in. diameter up to 1 in., and square-head setscrews from $\frac{1}{4}$ in. up to 1 in., and give dimensions of the screws generally.

Springs and Spring Material.

THE revision of the series of B.S. Specifications for railway rolling stock materials, which has been in hand for some years, has now been completed by the issue of the revised edition of Part 3 of Report No. 24, which deals with laminated, volute, and helical springs, and steel for laminated, volute, and helical springs.

The changes in the chemical composition of the steel are among the principal modifications that have been made in the revised issue. In the case of laminated springs the wide range of carbon limits which was originally given has now been divided into two separate ranges, one suitable for springs which are to be subsequently water-hardened, and the other for springs which are to be oil-hardened.

In the case of volute and helical springs the chemical composition of the material has been amplified by the addition of limits for silicon and manganese.

Copies of these specifications (Nos. 450 and 451, 1932, and No. 24, Part 3, 1932) may be obtained from The Publications Department, British Standards Institution, 28, Victoria Street, S.W. 1, price 2s. 2d. each, post free.

Austenitic Cast Irons

Recent developments have shown that valuable properties are conferred on cast irons by proportions of special alloys sufficient to produce an austenitic structure. These special cast irons are remarkable for their corrosion- and heat-resistance; they possess a high coefficient of expansion, a high electrical resistance, and are non-magnetic. Much useful information on this group of cast irons is contained in a recent publication by the Mond Nickel Co., Ltd., from which this article has been extracted.

As a result of recent investigations it has been realised that the production of the austenitic structure in cast iron by the use of larger proportions of such elements as nickel, copper, manganese, etc., provides materials which have many valuable industrial features. In comparison with ordinary cast iron, these austenitic cast irons have a marked degree of corrosion-resistance, a superior resistance to the effects of heat, a high electrical resistance coupled with a low temperature coefficient of resistance, a high coefficient of thermal expansion, and, with suitable compositions, are non-magnetic.

In mechanical properties the austenitic irons do not differ much from ordinary cast iron. Their strength, while naturally depending on composition, is in some cases as high as for good quality engineering cast iron. They are also tough, and have measurable ductility, 2 to 3% elongation frequently being recorded in tensile tests. The hardness of the pure austenitic structure is low, but the hardness of castings can be varied at will by modifications of composition.

Attention must be given to the proportions of elements necessary to produce the austenitic structure in order that the particular properties desired will be developed to the best advantage. It has been shown, for instance, as a result of researches, that a minimum of 20% of nickel must be added to an ordinary cast-iron base to render the castings austenitic. It is generally advisable, however, to increase the nickel or other austenite-forming element to 3 or 5% above this minimum value, in order to ensure that the castings are fully austenitic, and therefore readily machinable in all sections and under all conditions of treatment.

Copper assists in the formation of the austenitic structure in the cast iron, but as only about 1·5 to 2% of this element can generally be alloyed with cast iron, it is of little value by itself. It has been found, however, that the solubility of copper is increased in the presence of nickel, and that a combination of two parts of nickel with one part of copper can be alloyed with cast iron in all proportions. Under these conditions the copper assists the nickel in the production of the austenitic structure, and in its presence a lower proportion of nickel will give the desired result. Commercial austenitic cast irons have been developed with 14% nickel and 7% copper. This composition can be readily produced by the direct addition of "Monel Metal," which consists of nickel and copper in the required proportions of two to one.

Manganese may also be used in conjunction with nickel in the austenitic cast irons, one part of manganese being roughly equivalent to two parts of nickel. For practical purposes the amount of manganese that may be added is limited to about 5%. Above this percentage the presence of manganese carbides impairs the machinability of the castings. This element enters into the composition of the non-magnetic cast iron, developed by S. E. Dawson in collaboration with Messrs. Ferranti, Ltd., under the name of "Nomag," the austenitic structure being developed by the addition of slightly more than 10% nickel and 5% of manganese.

Chromium up to 5 or 6% may be added to most of the austenitic cast irons, with beneficial effects on strength, corrosion- and heat-resistance. It is not yet clear whether chromium is effective in the production of the austenitic structure in cast irons, and above 6% there is a tendency to the formation of structures containing chromium carbide which are in consequence hard and brittle.

These compositions are only sufficient to give structures just in the austenitic range, and it is frequently desirable to increase the proportions considerably above these percentages in order to improve special properties. The special corrosion-resistant cast iron, containing up to 40% nickel with 15% chromium, is an example of this kind. With the higher proportions it will be understood that the limiting amounts of the various substitution elements which may be added are also appreciably increased.

TABLE I.

COMPARATIVE RATES OF CORROSION.[1]

Reagent.	Austenitic Cast Iron.	Ordinary Cast Iron.	Brass.	Bronze.
5% sulphuric acid cold	1	475·0	1·12	1·08
10% " " at 100° C.	1	195·0	0·15	0·15
78% " " at 100° C.	1	1·95	—	0·08
5% hydrochloric acid	1	185·0	13·0	24·0
25% acetic acid	1	400·0	2·75	2·22
Salt spray	1	2·9	0·27	0·08
Sea-water	1	5·0	0·5	2·15

TABLE II.

CORROSION TESTS: WEIGHT LOSS IN MILLIGRAMMES PER SQUARE DECIMETRE PER DAY.[2]

Reagent.	Austenitic Cast Iron. (1)	Ordinary Cast Iron. (2)
Atmosphere.....	Rusts Superficially	Rusts Badly
" 30 days.....	9·5	59·7
" 90 days.....	7·9	63·5
" 1½ years	3·5	35·0
Water spray, vertical	6·6	207·5
" horizontal	17·6	244
Aerated tap-water	7·8	67·2
3% salt solution	50·0	190
12½% fermented molasses sol.....	10·0	360
Bad boiler water, 95° C.	110	660
Ferric sulphate	17,000	32,000
5% sulphuric acid, aerated.....	350	30,000
5% hydrochloric acid, aerated	507	26,665
10% "	598	29,475
20% "	1,111	33,270
Hot caustic.....	30·0	430

Probably the most important feature of the austenitic cast irons is their resistance to corrosion attack. Each corrosion problem must be studied by itself, because a material resistant to one type of attack is not necessarily resistant to another, but by modifying the compositions of austenitic cast irons, alloys presenting a very useful resistance to many corrosive media are available. In corrosion-resisting applications the austenitic cast irons containing proportions of nickel, copper, and chromium have received most attention. Such irons are manufactured under such names as "Nimol," "Ni-Resist," etc., and

1 M. Ballay, "Recherches sur quelques fontes au nickel et au cuivre," *Revue de Metallurgie*, 1929, vol. 26, p. 538.

2 J. S. Vanick and P. D. Mercia, "Corrosion- and Heat-resistant Nickel-Copper-Chromium Cast Iron," *Trans. Amer. Soc. Steel Treating*, 1930, vol. 18, pp. 925-934.

generally contain 14 or 15% of nickel, 6 to 7% of copper, and from 2 to 4% of chromium. Tables I. and II., which are taken from different sources, give results of corrosion tests carried out with alloys of this type. But it will be appreciated that when a special corrosion problem has to be met, other compositions of austenitic cast iron, containing higher percentages of alloying elements, in many cases offer superior service.

Under certain conditions austenitic cast irons can be regarded as behaving in a similar manner to such non-ferrous alloys as brass and bronze in their resistance to corrosion. There are, of course, notable exceptions, as, for example, attack by hydrochloric acid, in which austenitic cast iron offers a high degree of resistance. These cast irons are of special interest in their resistance to attack by weak sulphuric acid. Investigations have shown that the rate of attack on the special iron is one-fiftieth that of the ordinary material. Results have been obtained which indicate the resistance of austenitic iron to be sometimes as much as 500 times that of ordinary iron.

For chemical plant the austenitic cast irons are available as castings of all types, the metal being as adaptable as ordinary cast iron, but it is necessary to exceed slightly the minimum composition of alloys essential to produce the austenitic structure, as below this minimum traces of martensite are liable to be found in the metal, and while machining such an iron a distinct tendency of the metal to harden under the tool is encountered. This phenomenon is similar to that met in machining some of the austenitic steels, when the structure of the metal tends to revert to the martenitic state on being deformed. This may prove troublesome in the machine shop, and use should be made of sufficient alloy elements to avoid it.

Austenitic cast iron, × 500

Austenitic iron containing traces of martensite, × 500

The austenitic cast irons show marked superiority over ordinary cast iron when subjected to elevated temperatures. In regard to the latter, it is now generally believed that the incidence of the critical range round about a temperature of 700° C. in ordinary cast iron—which causes internal structural change in the metal, accompanied by volume change—tends on repeated heating and cooling to open up the metal, thus permitting access of the atmosphere with resultant internal oxidation and deterioration. This internal oxidation is accompanied by a permanent increase in volume, which causes distortion and frequently fracture. In the austenitic cast irons there are no critical changes corresponding to those found in ordinary cast iron, so that there is no tendency for the metal to open up on heating. Further, the austenitic structure is found to be more resistant to oxidation, so that the castings do not tend to scale and burn as in the case of ordinary cast iron.

For heat-resisting applications it is beneficial to use chromium up to the highest limit compatible with the strength and machining requirements of the castings, chromium assisting in improving the oxidation resistance of the body of the metal. Generally, up to 5% of chromium may be used in these compositions without introducing too much difficulty in machining. Higher percentages may be used where the castings do not have to be machined, with further improvement in the heat-resisting properties of the iron.

A recent development in this field is the austenitic nickel-silicon cast iron known as "Nicrosilal." This alloy, which has been developed by the British Cast Iron Research Association, consists essentially of an iron in the austenitic condition by virtue of the presence of 18% of nickel. The heat and scale resistance of this alloy has been enhanced by the use of a small proportion of chromium and an abnormally high silicon content, the latter being as much as 6%. According to Pearce,[3] Nicrosilal will not scale even up to its melting point, at about 1,150° C., and a sample heated to 1,000° C. in a gas muffle for periods aggregating 3½ hours showed a growth of only 1·3% in volume, which is about one-quarter of the thermal expansion at this temperature.

The austenitic cast irons are non-magnetic when the proportions of added elements are under suitable control, and this property enables these irons to provide a solution for problems in the electrical industry. The non-magnetic cast iron, "Nomag," previously mentioned, has a permeability of approximately unity. In selecting a composition of austenitic cast iron for non-magnetic applications care should be taken to see that the alloy additions are not too high. Generally, it is found that austenitic cast irons possess a specific electrical resistance about 50% higher than of ordinary cast iron, whilst at the same time they have the added advantage of a relatively low-resistance temperature coefficient which renders them particularly useful for resistance grids. No special difficulties are experienced in the foundry or the machine shop with these cast irons. When the quantity required is sufficiently large the most economical method of making up the metal is by passing the cast-iron base with the special additions directly through the cupola. For the alloy addition to the cupola a special pig is available which is calculated to contain nickel, copper, and chromium in the requisite proportions suitable for most of the corrosion and heat-resisting castings required in austenitic cast iron. Where the demand for special castings is not sufficient to justify the full working of a cupola for these irons, crucible melting may be employed, or rotary or reverberatory furnaces may be used. The shrinkage is greater than with ordinary cast iron, and corresponds more closely with that for aluminium, while the size and position of heads, risers, etc., should be as used for casting aluminium alloys.

When the composition of an austenitic cast iron is properly balanced, it may frequently be found that the metal cuts more easily than ordinary engineering iron castings. If they are found to be on the hard side, however, they may be softened by an annealing treatment, which consists in heating to 950°–1,000° C., and subsequently quenching in oil or cooling in an air blast.

3 J. G. Pearce, "Recent Developments in Cast Iron," *Metallurgia*, 1932, vol. 5, No. 27 pp. 81-82.

METALLURGIA

The British Journal of Metals

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METALLURGIA

THE BRITISH JOURNAL OF METALS.

WILL CONFIDENCE BE RESTORED?

THE Tariff Commission's scheme for the protection of the iron and steel industry creates a new position and the prospects of the industry are certainly brighter. The imposition of a further duty, making 33⅓ in all, on certain classes of heavy iron and steel products as a temporary measure is no doubt a wise course, particularly as the Advisory Committee have made it clear that, should the present abnormal competition from abroad continue, it would not hesitate to recommend the continuance of these emergency duties for as long as may be considered necessary. Meanwhile a National Committee has been appointed to prepare a more definite scheme that can be accepted as a permanent means of protecting the industry, without injury to the home user of iron and steel who depends largely on export trade. Many complex problems will need to be overcome, for cheap iron and steel is one of the vital necessities of our industrial and economic life. The subject will need very careful consideration and thorough examination in order that a balanced judgment can be reached.

Personal considerations will need to be set aside and the subject discussed wholly in the national interest. It must be appreciated that the iron and steel industry cannot be prosperous unless it can sell its products; and it can only sell its products if the industries using them are flourishing. Those industries being largely export industries can only maintain and develop their exports if they can be assured of getting from the iron and steel industry the requisite material of the right quality and at the lowest possible price. The main value of a tariff, therefore, will be to afford the industry the opportunity of putting itself in order on the lines best adapted to this country, and the diversified nature of the demands which have to be met; the methods of organisation adopted in other countries are not necessarily appropriate in this country.

It should not be assumed that the productive efficiency of the majority of the plants in this country is necessarily behind those of our competitors overseas. In many instances present plant is more economical in use for meeting the comparatively small demands. It must be remembered that during recent years the demands from the home market have fallen gradually, and since standing charges remain almost stationary, there has been little incentive and practically no capital to carry out desirable improvements. Now that there is a likelihood of securing the home market, however, which, in due course, will ensure need of larger outputs, improvements will be made in plants as soon as money becomes available.

But while the condition of the iron and steel industry is in urgent need of resuscitation, the imposition of a tariff is only one of the means likely to have a beneficial effect. In every country there are urgent matters which need a definite solution, and in which the future of the iron and steel industry and all other industries is rigidly bound. A return to normal industrial prosperity is not possible until some formula has been thrashed out that will restore world confidence. Various plans, schemes, and arrangements have been made to cope with the chaos and muddle originally created by the Versailles Treaty, and now another effort is to be made at Lausanne. After the disappointments of Geneva it is difficult to expect a restoration of confidence in the results of the deliberations at Lausanne, but there is a spirit abroad among the peoples of the world that must sooner or later bear fruit.

It is significant that America is prepared to co-operate in economic discussions, and although there are to be many restrictions, notably in regard to thorny subjects like tariffs, and debts, and reparations, three basic problems might be considered in which the co-operation of America would be invaluable. These include the problem of raising the world's price level in order to check the paralysis by which trade is everywhere threatened; the problem of providing a stable international currency; and the problem of co-operation among central banks. World confidence is bound up in a solution of these problems, and it may be that the Lausanne Conference will facilitate their solution by clearing the ground, and make further advance possible. If, however, a solution of the problems at Lausanne is not agreed upon and a settlement is merely postponed, it is practically certain that any world economic conference that may be arranged for the autumn will be doomed to failure. Under such conditions it would be impossible to reach agreement on currency problems or the price level, as payments regarding inter-governmental debts would remain uncertain.

The coming Imperial Economic Conference at Ottawa offers possibilities of increased confidence between the various states within the Empire. It is important to remember that such duties as are imposed between members of the Empire are not applied simply for bargaining purposes, but in order that each State can proceed with its development by legitimate means which favour its own people first and the Empire next, and the prospects of substantial reductions of Dominion tariffs are not particularly bright. The Dominions were brought under the general tariff, but levying of the duties was postponed until November. Evidently the Government intends to confirm this provisional exemption—leaving Dominion products on the free list—if at Ottawa the Dominions offer adequate concessions in return; otherwise it is presumed the suspended duties will be brought into force, with whatever modifications may seem to be justified by such offers as can be obtained. Many complications will be encountered at this Conference and it is very unlikely that trade agreements on a reciprocatory basis will be arranged with the Dominions in the short time available, but, as a result of free discussion, preliminary arrangements may be made between two or more of the Governments which will restore confidence and ultimately result in such agreements.

The advantages of an economically sound British Empire, which may possibly accrue from the Ottawa Conference, are considerable; the imposition of duties on imported goods will no doubt give greater security to manufacturers in having the support of the home market; but the greatest hope for the revival of industry in Britain, as elsewhere, lies in a settlement of reparations. No agreement can be entered into regarding international currency or the price level until definite arrangements are made in respect of these war debts. It is, then, from the deliberations at Lausanne that we must look for the promise of a rapid return to greater confidence amongst the nations and the stability engendered as a result of workable solutions. These would aid in the settlement of world problems and would be more effective in restoring industrial prosperity than National or Imperial measures.

A YEAR'S REVIEW OF THE INSTITUTE OF BRITISH FOUNDRYMEN.

By Andrew Harley (*Ex-President*).

ON looking back over the past year my chief impression is that in spite of the depressing condition of trade generally our Institute is full of vitality. This is shown in every aspect of our activities. For example, our membership shows a substantial increase, our accounts show a very respectable balance on the right side, new sections of the Institute have been initiated at Preston and Lincoln, and our Scottish branch have arranged meetings for Edinburgh and district, while maintaining the usual programme of meetings in Glasgow and Falkirk.

Another gratifying feature that may be mentioned is the splendid attendance at the General Council meetings. Four meetings have been held—namely, at Birmingham, Sheffield, London, and Blackpool,—and the average attendance was forty-six. When it is considered that every district in Great Britain is represented in our Council it is a great tribute that the expenditure of time and money is not grudged in serving the interests of the Institute.

In addition to the administrative work of the organisation the General Council have launched a technical scheme for the training of young foundrymen, and in conjunction with the City and Guilds of London Institute regular examinations will be held in all the important centres of technical education. Although it was appreciated at the outset that the chief obstacle to the success of this scheme would be the apathy of the foundry apprentices, for whom it was primarily intended, it is felt that the results of the first year have been unexpectedly encouraging, and have more than justified the establishment of the scheme. It must be realised that the training of foundry apprentices has always been a difficult problem, and the numbers attending evening classes have usually been proportionately small. There are, however, indications that, as the scheme becomes better known and the value of National Certificates recognised, greater numbers of apprentices will strive to earn the qualification and will pursue technical studies for that purpose.

Another recent development of our work has been the establishment of a technical committee. For this Committee five sub-committees were formed to deal with subjects which include cast iron, malleable iron, steel, non-ferrous metals, and sands and refractories. These committees have now been in active operation over twelve months, during which time eight meetings and numerous sub-committee meetings have been held, the first general report of which is included in this year's annual report presented at the Newcastle Conference.

In the initial stages the Committee has confined itself mainly to exploratory work, with the object of examining, analysing, tabulating, and correlating knowledge which was already in existence, and to indicate directions in which information might be usefully sought. To facilitate co-operation between the Technical Commitee and the British Cast Iron Research Association, a Liaison Committee has been formed.

Each sub-committee has collected and tabulated specifications dealing with its own subjects, with a view to simpifying and standardising such specifications. The progress of the work, in the face of many difficulties, has been such that the Technical Committee felt justified in presenting a paper at the Conference giving a *resume* of the work performed by the sub-committee dealing with malleable iron. The striking feature about this is that no financial aid can at present be given by the General Council towards the work of the Technical Committee. Here again much personal expenditure has been involved, and this has only been made possible by the self-sacrifice of its members and the goodwill of many firms who have rendered generous help in making the investigations possible.

The Institute is engaged in valuable work, not only in accumulating data and information of particular importance to foundrymen and all associated with the production of castings, but in raising the whole technical standard of the foundry industry. It will be appreciated that unless knowledge is imparted and brought into line with the foundry with a view to its resuscitation and maintenance on a high standard of efficiency, much valuable work will have been wasted. The General Council takes a very serious view of this aspect, but the responsibility rests primarily with those engaged in or associated with the industry, who should be definitely interested in the Institute's activities, not only to secure the advantages of co-operation in the solution of problems, but also to render assistance in overcoming the difficulties of other members. It is in this way that preparation can be made to meet present and future exigencies, in effecting progress, and in raising the status of the foundryman.

Branches of the Institute exist at various centres throughout the country and all who are desirous of rendering assistance will find ample scope for their activities at any of these branches.

During my presidential year I have visited most of the branches, and I have to record my admiration of the devoted work of the branch officers and branch councillors. All the work performed is voluntary. Eighty-five papers have been given, and the high technical importance of these can be estimated by reference to our "Proceedings," a volume of which is published annually.

A Copper Refinery for Great Britain.

A COMPANY has been formed under the title of British Copper Refiners, Ltd., with the object of producing high conductivity copper for electrical purposes. The new company is closely associated with British Insulated Cables, Ltd., which will thus be able to supply consumers of copper and copper products with metal refined in Britain and produced by British labour and capital, and it is of interest to note that this refinery will be the first and only works of its kind in Great Britain.

The raw material used will be in the form of blister copper, and the finished products will embrace copper bars, billets, cakes, and slabs of exceptional purity, these forming in turn the raw material for the manufacture of underground and overhead cables, winding wires, and other conductors for electrical purposes, as well as for high-class copper sheets, tubes, sections, and other mechanical requirements. Production has already been made on a sufficient scale to show that electrical conductivity as high as 101-102% of the standard may be expected.

There will, of course, be considerable competition with existing refineries in America, France, Belgium, and Germany, but on the facts available the present project seems to contain the elements of success; and in any case, the reproach that this country is behindhand in its facilities for the complete treatment of copper from the raw state up to the finished article, will have been removed.

The works will be situated at Prescot, Lancashire, where ample transport facilities are available; and the very latest type of plant and equipment, based on international experience, will be employed, with a view to ensuring the very highest possible quality as well as keeping the cost of production to the lowest possible minimum.

The initial maximum output of the plant at present to be installed will be 1,000 tons per week, but provision is being made whereby extensions of buildings and machinery can be carried out. Work has already been commenced on the site, and it is expected that the plant will be in production towards the end of the year.

The raw material will be imported from the Roan Antelope Company's mine in Rhodesia, and in this way the ideal of Empire-produced copper products will be achieved.

The Ural-Kuznetsk Combine.

A brief summary of the immense possibilities of this Russian organisation.

THE industries of pre-war Russia are in the main developed on supplies of metals from the South and coal from the Don Basin. A considerable part of Eastern Russia for centuries remained a backward boundary amidst inexhaustible natural resources. Such a geographic distribution of industry was inacceptable to a planned system of economy aiming at an even development of the productive forces of the country as a whole.

The formation of the Ural-Kuznetsk Combine was to create in the East of the Union a second big base of supply of coal and metal, making it possible to develop the productive forces of extensive, untouched territories and the natural resources of Western Siberia, Kazakstan, and Bashkir. The power resources contained in the area covered by the Ural-Kuznetsk Combine are not only the richest in the U.S.S.R., but in the world. In the Kuznetsk Basin alone the estimated deposits of coal are 400 milliard tons. The territory of the Kuznetsk Basin is equal to that of the Don Basin, but its coal deposits are six times as large. Moreover, while 75% of the coal from the Don Basin is poor coal, the coal of the Kuznetsk Basin is mainly of a rich variety with a large content of volatile substances, making splendid material for the development of a chemical industry. The coal from Minusinsk in Western Siberia, from Karagandinsk in Kazakstan, and from Kisolevsk in the Urals, is of a similar kind. There are now springing up in these backward borderlands huge industrial concerns equipped with the most modern machinery.

The Combine embraces a new country, in size equal to a third of the territory of the United States. The solid foundations for this biggest combine in the world were laid in the first five-year plan. The Magnitogorsk and Kuznetsk metallurgical works—the biggest in the world—are already in partial operation. The output of one of the Magnitogorsk blast furnaces is over a thousand tons of pig iron a day. This year the first sections of the Magnitogorsk and Kuznetsk factories will be put into operation. Intensive exploitation is proceeding of the new coal regions. This year the coal fields of the Kuznetsk Basin and Karaganda are estimated to yield about 14 million tons of coal, 11 million tons from the first, and 2·5 million tons from the second, which is practically half the total quantity raised in pre-war Russia. The first sections of the Bereznikovsk chemical combine are already at work. The Magnitogorsk, Kuznetsk, and Kemerovsk coke and chemical plants are going up at a great rate, and so are the first sections of the Krasno-Uralsk, Belovsk, and Cheliabinsk non-ferrous metal works. The Ural machine-building works are practically completed, and the first section of the Cheliabinsk tractor works has been put into operation.

Much attention has been paid, too, to the increase of the supply of electric power in the region. This year the total capacity of the generating stations will be brought up to 930,000 kw., as compared with 150,000 kw. in 1927-28.

The second five-year plan opens up immense prospects for the further development of the Ural-Kuznetsk Combine. It is estimated that in 1937 the production of pig iron will reach 9 to 10 million tons, as much as the total output of the entire Soviet industry this year. The output of coal in the last year of the second five-year plan is estimated to reach 110 million tons, approximately double the quantity raised in the whole of the Union in 1931, and 20 million tons more than the total quantity of coal expected as the yield from all the coalfields of the Union in the present year. By the end of the second five-year plan the capacity of the generating stations of the Ural-Kuznetsk Combine is estimated to reach 7·2 million kilowatts and the output of electric power 35 million kilowatt hours, which is three times the total output of electric power in the whole of the Union last year.

Unlike the coal and metal regions in the Ukraine, the territory of the Ural-Kuznetsk Combine is rich in deposits of non-ferrous metals, which will make it possible to develop a non-ferrous metal industry. The output of copper in the region in 1937 is estimated to reach 400,000 tons, as against a total output of 36,000 tons in the whole of the Union in 1931.

Big deposits of lignite coal in the north-east of the Kuznetsk Basin will make it possible to establish a chemical industry for the production of liquid fuel and various nitrogenous products. Lastly, the Ural-Kuznetsk Combine is to manufacture machinery on a large scale.

The natural power resources of the Combine are concentrated in the Kuznetsk and Minusinsk Basins, whilst the iron deposits, estimated at about 1,200 million tons, are in the Urals. As this necessitates the transportation of coal from the Kuznetsk Basin to the Urals, and ore from the Urals to the Kuznetsk Basin over a distance of 2,000 km., it is intended to extend the existing railway system to a considerable extent and to electrify a large part of it.

Correspondence.

Degasifying Molten Metal.

June 1, 1932.

The Editor, METALLURGIA.

Dear Sir,—Your correspondent, Mr. B. Sheynin, has raised a most interesting point in his letter which appears in the May issue of your journal. A process which embodies some of the suggestions as applied to molten refined iron was introduced by this company some years ago. This process, known as the degasification process, has been in operation continuously, dealing with large unit quantities of metal in the manufacture of our degasified refined iron.

In this process, which operates in a large unit, treating quantities of from 10 to 15 tons at a time, the metal is taken from the furnaces or refineries for treatment. The degasification plant consists of a large cylindrical furnace fired by means of oil burners, so that the metal taken from the refineries can be maintained at a suitable temperature for the degasification process. The process is effected by the introduction of a powerful stirring device lowered into the metal after the removal of the furnace roof. This device consists of four vertical rods, coated with a suitable refractory coating and arranged to rotate in the metal at a constant speed of different radii. The period of time during which the metal is subjected to this agitation is dependent upon the character and the amount of metal to be treated. The agitation produced is of a violent character, and the molten mass of metal acquires a rotational velocity of at least 400 ft. per min.

The effect of the violent agitation and rotation of the metal, in addition to ensuring thorough mixing of the metal, tends to eliminate a good deal of the dissolved gas content and suspended undissolved impurities. The effect of this is quite distinctly apparent in the improved running properties and increased "life" of the liquid metal. In its application to pig-iron, this process was the first attempt to apply degasification processes to the production of pig iron.

The process has now been in operation some years, and during this period it has been amply demonstrated that castings made from refined iron treated in this manner possess increased soundness and freedom from included matters.—Yours, etc.,

(Signed) J. E. HURST,
Technical Director.

Bradley and Foster, Ltd.,
Darlaston Blast Furnaces,
Darlaston.

Aluminium Sheet Production

By Robert J. Anderson, D.Sc.

Part XIII.—Finish Rolling.*

The essential differences in the finish rolling of flat-sheet stock.

Finish Rolling of Flat Sheet.

After sheet stock has been roughed, it is delivered to the finishing mills for rolling to gauge and producing the desired surface finish. The stock is handled on buggies, skids, or tables, and should not be piled on the floor.

Before starting the finishing, the roller should check each lot with its corresponding mill ticket as regards size and gauge. This is done to ensure that the proper lot has been delivered and that it will finish to the dimensions specified. Then the sheets should be examined to determine whether they have been properly roughed, and also for the presence of blisters, dirt, slivers, and other surface defects. Sheets which have been so poorly roughed that they probably will not properly finish should be thrown out. Some surface defects can be removed by dressing the sheets locally with a wire scratch brush. Sheets containing defects which are deep-seated and cannot be removed should be discarded or set aside for subsequent disposition. There is no sense in trying to process defective sheets which will not finish satisfactorily.

Proper roll set is very important. If the roller is familiar with the condition of the mill, or if a succession of lots of the same kind is being rolled, he may be able to make the set precisely so as to give the correct draft. Otherwise, it is better to make the roll set too loose than too close. If the rolls are too far apart for the thickness and width of stock being finished, the sheet draws in the middle and not at the sides; this causes buckles and corrugations. Also, under this condition, the sheet will whip on the pass. This results in whip marks on the rolls and sheet and also causes the tail of the sheet to split down the middle. Certain of the adverse results generally associated with a too-high roll set may be due to improper roughing. The roll set should be checked after a couple of passes by gauging both sides of the sheet. If the roll set is too tight, the sheet will pinch and consequently mark the rolls. This marking is of the nature of a local coating streak. When rolls have been marked by a pinch, the rolling must be stopped and the rolls ground to remove the coating. Also, if the rolls are too close together, the side portions of the sheet will likely be drawn to gauge before the heavy centre has been worked out; then the sheet will not properly flatten on the mill. It should also be mentioned that a sheet may split in from the side edges owing to lack of uniform pressure across the width, due either to improper roughing or incorrect roll set.

The above points apply both to roughing and finishing, but assume more importance in finishing because of the diminished body of stock which is available for work. This is self-evident, and the matter need not be here enlarged upon.

Care should be taken that the pair of rolls is in precise alignment, so that the draft is not greater on one side than the other. The alignment of rolls may be changed as required by adjusting the screw on either side of the mill. In the case of screws actuated by hand wrenches through notched wheels, the spanner bar has holes drilled in one end for the adjustment. Extending or shortening the working length of the spanner by one hole makes a difference of 0·001 in., or other small amount, in the alignment. In the case of screws driven by hand-wheels through gearing, the adjustment may be made by means of thin liners placed between the end of the screw and the bronze block. A piece of paper may be used as a liner.

(*Continued from May issue, page* 14.)

Speaking generally, in finishing medium and light-gauge material, the single sheet (or pack) may be given about forty passes with the original roll set. This should bring the stock nearly to gauge and make it flat. The rolls are then given a slight additional set, and the sheet is passed five or six times to bring it to the finished gauge. When heavy gauges and plate are finished (with more than one or two sets of the rolls), the heavy centre should not be worked out entirely before making the successive sets. The centre should be reduced gradually, some small extra thickness being carried along from set to set.

Large sheets, being troublesome to handle, are rolled singly; small to medium-size sheets and packs are rolled in pairs. When rolled in pairs, one sheet is being passed into the mill by the roller, while the other sheet is being returned over the upper roll by the catcher. From two to four men are required to operate a finishing mill, depending on the size of the sheets. Thus, for handling very large sheets, a roller and helper and two catchers are needed; with medium-size sheets, a roller and two catchers may be used; and with small sheets and packs a roller and a catcher are employed. The output in finish rolling varies considerably, depending on the size and gauge, as well as the surface finish. In one plant the production rate varied from 100 lb. to 200 lb. per hour, and the average over a period of one year for all classes of material processed was about 125 lb. per hour.

Details of finish-rolling practice must be varied considerably, depending on the gauge, size, temper, and surface finish.

Rolling to Gauge.—In considering the details of passing and drafting in finish rolling, it is convenient to classify sheet according to gauge. Thus, the material may be classified as plate ($\frac{1}{2}$ in. to $\frac{1}{8}$ in. thick), heavy gauge (Nos. 10 to 14 Brown and Sharpe), medium gauge (Nos. 15 to 19), and light gauge (No. 20 and lighter), which is to be pack rolled. The light gauges may be further classified according to the number of sheets rolled in a pack.

Referring first to plate; it is more troublesome to roll this material to gauge and produce flatness than is the case with sheet. Stock for heavy plate comes directly from the hot mill, and is not slabbed or roughed; stock for light plate may be roughed before finishing. As a general proposition, a roll set is made before each pass, and the draft is progressively decreased as the final gauge thickness is approached. The percentage of reduction per pass cannot be stated precisely; the width, temper, variation, or unevenness in thickness of the hot-mill slab, final gauge and general condition of the slab all have influence on the draft. In finishing light plate of moderate width, the draft

Fig. 2.—End curling of slabs as affected by roll set.

on the first pass may be 0·02 in. to 0·03 in.; this is gradually reduced to 0·005 in. on the last pass. In the early stages of the passing, if the roll set is correct, the front end of the slab will turn down slightly, as shown in A of Fig. 2; if the roll set is too high, the front end will turn up, as indicated in B or C of Fig. 2. As the rolling proceeds, the thickness of the slab should be measured often with a micrometer in order to check the reductions.

The plate should acquire flatness in the early stages of the rolling and then should be kept flat so far as possible by reducing the thickness a proper amount on each succeeding pass. This is especially important as the final thickness is approached when sufficient stock should be available, so that the plate will finish at gauge and remain flat on the last pass. Thus, if insufficient thickness is available, proper draft which will flatten the plate will bring it below gauge, and conversely sufficient draft to bring the stock to gauge will not flatten it. On the last pass or two the roller must adjust the drafting as required, according to the thickness of the plate, its appearance, and behaviour on the prior passes. As an example, it may be assumed that plate is being rolled to 0·250 in. thick, the late drafts are about 0·01 in. each, and the stock has been reduced to 0·265 in. Depending on conditions, the plate may be finished with one pass and a draft of 0·015 in.; two passes, with successive drafts of 0·005 in. and 0·007 in. may be made, the plate being finished a little heavy; or two passes with successive drafts of 0·008 in. and 0·01 in. may be made, the plate being finished a little light. When the final reduction to gauge is made with two passes, it may be found that insufficient stock is left after the first pass to flatten the plate properly on the second pass with the draft that will bring it to the exact gauge. In such a case sufficient draft should be applied to flatten the material, even though it is thereby rolled somewhat below gauge. Rather large thickness tolerances are allowed for plate (*vide* Table IX. of the first article in this series).

Heavy-gauge sheet (Nos. 10 to 14) is rolled somewhat like light plate, but instead of setting a draft for each pass from two to five passes are made with each roll set. As will be recalled, stock for sheet is first slabbed and roughed, and consequently carries a coating. The coating is removed by the rolling in producing bright flat sheet. Roll sets in processing heavy gauges are, of course, lighter than with plate. The sheets may be worked lightly at first until the coating is removed and large corrugations appear across the width. As soon as the sheet is rolled reasonably flat on a given set of the rolls a new set is made. If sheets are given too many passes at one set, they tend to corrugate and vibration marks, due to whip, appear on the tail surfaces. A new set should be made when vibration marks become visible. If such marks are apparent on the tails as the finish gauge is approached, they can often be removed by reversing the sheet. The previous back end is fed to the rolls, and the roller holds down on the new tail (former front end), so as to minimise vibration. In doing this, the sheets should be turned over "end for end" and not around (in a horizontal plane). So handled, the right- and left-hand sides of the sheets are in the same positions with respect to the rolls as before the reversal. The same general method of drafting is used in attaining the required gauge and flatness as described above in the case of plate.

Referring now to medium-gauge sheet, it may be said in a general way that this is rolled with more passes and fewer roll sets than heavy-gauge material. Medium-gauge sheet is produced in a wide range of widths and tempers, and the practice of finish rolling must be varied accordingly. It was pointed out above that sheet may be finished by giving a large number of passes with one set of the rolls, thereby bringing the stock nearly to gauge; then a slight additional set is made, and the sheet is rolled to gauge with about half a dozen passes. An alternative method is to roll with the proper number of passes and two sets of the rolls, the two drafts being about the same, or the first slightly heavier than the second. Thus, in the case of widths ranging from 18 in. to 26 in., sheet to finish 16-gauge (0·0508 in. thick) will probably have been roughed to about 0·065 in. The material may be finished by rolling at one set to 0·057 in. with 15 to 20 passes, and then with a second set to gauge with the same number of passes. Also, 18-gauge (0·0403 in. thick) sheet in the same widths may be run from about 0·051 in. to 0·045 in., with 15 passes and one set of the rolls, and then to gauge with the same number of passes and a second set.

When medium- and light-gauge sheet are dealt with the roller should hold the tail of the sheet up, so that the surface is pulled against the upper roll; this helps to prevent whipping on the pass as well as pinching. As a general rule, the tail should be pulled up on the first couple of passes when the drafting is started on a new roll set.

For widths greater than about 26 in., lighter drafts (more roll sets) and more passes are given. In finishing wide, medium-gauge material, special care must be taken to reduce the heavy centre gradually in order to prevent pinching on the first pass after a roll set has been made. In other words, the "backbone" of the sheet should not be worked out in the early stages of the rolling, but the centre should be reduced progressively and the sheet gradually flattened by the passes on the successive roll sets. As a rule, the greater the width the more passes are required to produce flatness. When the total number of passes is increased, the number of roll sets should also be increased and the draft per set correspondingly decreased. When a pair of wide sheets has been rolled almost to gauge, it may be found that the right-hand sides are appreciably lighter than the left-hand sides, or *vice versa*, the mill having gone out of alignment during the finishing. In this circumstance there is no use in making a screw adjustment until after the pair has been finished. If a small adjustment is made and the pair then passed, the sheets will likely pinch, or at best it will not be possible to flatten them. In order to flatten wide medium-gauge sheet at the finish it is sometimes necessary to jog the hand wrenches or screw-wheel very lightly, thereby making a slight set. Sufficient roll pressure is thus provided, so that the sheet will flatten with a couple of passes. On the other hand, in some cases it is necessary to jog the screws very lightly in the opposite direction, thereby raising the roll a minute distance, or, as is said in rolling-mill parlance, "relaxing the pressure," before making the flattening passes. The proper procedure is a matter of judgment, and depends upon the condition of the sheet.

When running a new lot of sheet on a mill, the width of which is different from that of the preceding lot, care should be taken to check the gauge thickness of the first pair finished. Of course, in processing any lot, the gauge of each sheet should be measured as finished. When sheets are rolled in pairs, one sheet may arrive at the finished gauge before the other. In this circumstance the first sheet should be "laid off" as finished; then the screws should be jogged slightly, and the other sheet rolled to gauge. When passing stock, the roller stands on the left-hand side of the feed table, and it is natural that he should apply his micrometer to the left-hand side of the sheet. Needless to say, perhaps, the right-hand side should be gauged frequently during the processing, and this should be done by the roller with his micrometer, and not by a catcher with the roller's micrometer or some other micrometer.

The pack rolling of light-gauge sheet is discussed below under an appropriate sub-heading

Bright Flat Sheet.—A bright, planished surface finish is produced on aluminium sheet by rolling in contact with bright polished rolls. Cast-iron rolls quickly pick up a coating when aluminium is passed; forged alloy-steel rolls do not so readily pick up a coating. Aluminium alloys do not coat rolls so readily and uniformly as does 99+% aluminium; the harder the alloy, in general, the less the tendency toward coating. In American practice, flat-sheet finishing mills have usually been equipped with cast-iron rolls. In order to keep these rolls bright and polished when the finishing passes are made, cloth buffs are employed. These are placed in contact with the rolls, and prevent coating formation. The construction of buffs is described in a later article (Part XV.). When bright flat sheet is finished, the sheet or rolls are swabbed from time to time

with kerosene. This lubrication helps to prevent the material from sticking to the rolls, tends to stop coating formation, and also improves the polish. Fig. 3 shows the roller's side of a flat-sheet mill, the rolls of which are highly polished. The buff contacting the top roll may be noted.

The degree of polish, or rather the brightness of surface finish, obtainable depends upon various factors. Other conditions being the same, a brighter surface is obtained when the sheet is finished on alloy-steel rolls equipped with buffs rather than on cast-iron rolls similarly equipped. If buffs are not used on steel rolls, the rolls should be cleaned and polished at suitable intervals. A brighter finish is obtainable if the stock is roughed on polished rather than coated rolls. When the coating on the roughed sheets is too heavy, the material may finish with a milky or streaked surface appearance. In some plants, when extra bright sheets are to be produced, kerosene or transformer oil (rather than an oil-water emulsion) is used as the lubricant in the hot break-down operation. If there is a ground-in coating of oil-water emulsion on the hot-mill slabs, the resultant sheets may have a mottled, milky surface finish. When kerosene or transformer oil is used as the lubricant in breaking down ingots, the slabs are relatively bright.

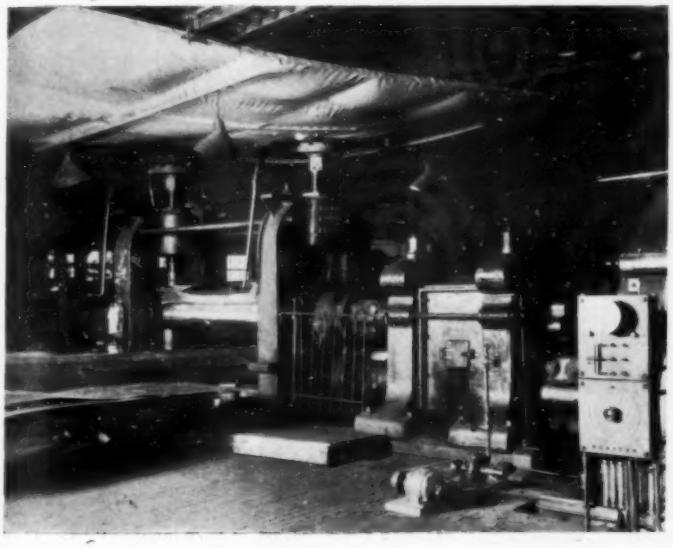

Fig. 3.—Mill with polished rolls for finish rolling bright flat aluminium sheet.

Light-gauge sheet rolled in pack is produced in the bright finish—not as grey plate. As is obvious, when a pack is passed only the bottom surface of the bottom sheet and the top surface of the top sheet contact the rolls. Pack-rolled sheets may be produced with a bright finish on one side or both sides. The positions of the sheets in the pack are to be changed about during the finishing, so that one side or both sides of each sheet are given some (greater or lesser) number of passes in contact with the rolls. In commercial material the polish or brightness of surface on pack-rolled sheets is not ordinarily so good as on sheets rolled separately. This follows, in part, because the latter have had more passes in contact with the roll surfaces.

Grey Plate.—Grey plate differs from bright flat sheet only as regards the surface finish. Practice employed in rolling the two products is the same except with respect to the condition of the roll surfaces, grey plate being finished on coated rolls. When aluminium is passed on a mill (equipped with cast-iron rolls) without buffs or without the use of a cutting-metal oil, a coating forms on the rolls. This coating consists of fine particles of aluminium, more or less oxidized, which have flaked off from the sheet and become attached to the rolls. When aluminium sheet is passed on mills having coated rolls, a grey semi-matte finish is imparted to the sheet surfaces. The coating on rolls must be properly maintained, care being taken that it does not become dirty or build up too heavily. This is important not only in the case of finishing mills run on grey plate, but also in the case of roughing mills. The coating must be removed from rolls when it becomes dirty or too thick, and a new coating then developed. Fig. 4 shows the finish rolling of grey plate; the coating on the top roll may be noted.

When it is desired to remove the coating for any reason, the rolls may be dressed by hand, using a mixture of emery and cup grease on a grinding stick; or the coating may be washed off with a solution of sodium hydroxide, followed by hand grinding if necessary

Kerosene is employed as the lubricant in finishing grey plate. This should be used sparingly. If too much is swabbed on, the colour is likely to be non-uniform or will at least be darkened; also, the surface will be smeary—particles of aluminium will rub off easily.

The grey-plate finish is not ordinarily produced on sheets rolled in pack. A uniform finish cannot be produced because the separate sheets in the pack move against each other and hence tend to rub off the coating.

Pack Rolling.—Pack rolling is practice for sheets to finish at about 20-gauge and lighter. In some plants, sheets to finish at 20-gauge in the intermediate tempers are rolled separately, and sheets to finish at 20-gauge as 2 S H (and 2 S O on annealing) are rolled two in a pack; sheets to finish 21-gauge and lighter in any temper are rolled in pack. As stated previously, the number of sheets in the pack is increased more or less progressively with decreasing thickness of the finishing gauge. Packs are built up during the course of roughing, and, generally speaking, the development may be started when the stock has been reduced to about 18-gauge.

When rolling in pack, care should be taken to keep the sheets in line at the side edges and ends. This helps to prevent cracking-in. If the ends are out of line, the end of a sheet may turn down and be caught by the roll strips or stripper-sticks on the catcher's side of the mill. Such an occurrence will rip the pack apart, cause marring of the sheet surfaces, and possibly prevent finishing. When necessary, the ends and sides of a pack may be trimmed during the course of rolling. On the initial passes, or after a roll set has been made, the pack should be held up so that it presses against the top roll. The roller should pull up and back, so that the pack is held taut and the ends are not free to flap. This helps to prevent pinching and yields smoother sheets.

In running stock to finish 21 to 24 gauge inclusive, it is usual to work two sheets in a pack. Sometimes the pack can be finished with one set of the rolls, but in other cases the total draft applied should be made in two sets. The procedure is governed by various factors, including the condition of the roughed pack, the finishing temper, width and shape of the finishing rolls in relation to that of the roughing rolls. These gauges may usually be finished with a total of 20 to 30 passes, for widths up to 32 in. The top and bottom sheets in a two-sheet pack will not roll to the same thickness if left in the same relative positions throughout the finishing. Hence, the positions are reversed during the course of rolling. The pack is not turned over, but the pair of sheets is shuffled once like a couple of cards. This reversal exposes the two surfaces of the sheets which were previously in contact to the rolls and permits polishing (brightening) those surfaces. The sheets may be reversed when the finishing is about half-done. Sheets should also be reversed during the roughing operation.

Generally, sheets to finish at 25 to 27 gauge inclusive are rolled three in a pack; some intermediate tempers in these gauges (*e.g.*, 25 gauge, 2 S 2) may be rolled two in a pack.

It is usual practice to finish pack-sheets 25 gauge and lighter with one roll set. Care must be taken in handling these light gauges to prevent wrinkling and kinking. In running a pack of three sheets, the position of the sheets must be

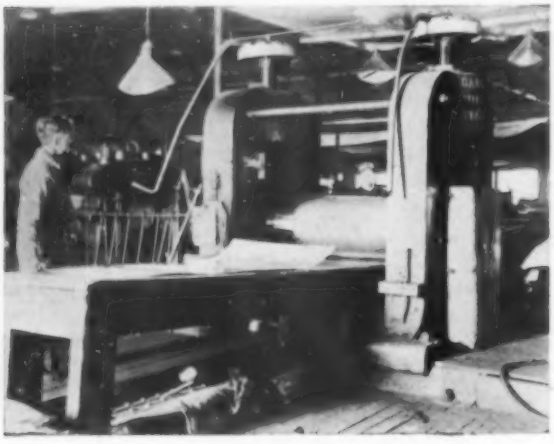

Fig. 4.—Finish rolling of grey plate.

changed successively, so that they can all be worked to the same gauge and surface finish. Sheets to finish at 28 to 30 gauge and sometimes as light as 32 gauge, are rolled four in a pack, with one roll set. On the way down to gauge, the sheets must be properly shuffled so that all surfaces on some passes come in contact with the rolls. This may be done by first reversing the top and bottom pairs; next the then top sheet is put on the bottom of the pack; and finally the then top and bottom pairs are reversed. The pack is, of course, given some passes after each change of position is made. As the final gauge is approached, the then top sheet may be shifted to the bottom before each pass, or two or three passes may be made after such change. The successive top sheets are successively shifted to the bottom. Handled in this manner, both surfaces of each sheet in the pack contact the rolls on, say, 6 to 10 passes.

In order to prevent kindling and wrinkling and to roll the pack flat, it may be necessary to shift the sheets one at a time, and give one pass, two at a time, and give two passes, or some other way. Sometimes it is necessary, during the course of finishing, to trim the ends or side edges of the sheets in order to promote flatness and stop a tendency toward wrinkling.

Scrupulous cleanliness must be observed in the finish rolling of bright flat sheet and grey plate. Care should be taken that no foreign particles fall on the rolls, sheet, or tables, as these will be forced into the surfaces on a pass, thereby marring the finish. Hand leathers and gloves should be clean, and especially should be free of grease. Sheet should be handled so that the edge of one is not pulled across the surface of another, otherwise unsightly scratches will result. Rolls should be kept in good condition; any marks should be ground off as soon as noticed. It is generally advisable to shear off cracked side edges and ends, during the course of rolling, so as to prevent further cracking, otherwise the stock may crack in so far that when it is delivered to the finishing department it cannot be sheared to the specified size.

(*To be continued.*)

Welding Copper

CONSIDERABLE advances have been made in the welding of copper, and this improved technique is undoubtedly reflected in the extended use of copper for a wide variety of purposes, the fabrication of which is simplified by the use of welding. The procedure adopted in welding copper is of considerable importance for successful results. This was emphasised by Mr. L. C. Percival, in a paper delivered recently on the subject before the Institution of Welding Engineers. The edges of the copper to be welded must be clean. Some of the preliminaries depend on the thickness of the copper to be welded. Thin sheet is nearly always flanged or turned up at right angles, in which case it is not necessary to add metal from the welding rod, the edges being simply fused down to form a welded seam. Copper, $\frac{3}{16}$ in. to $\frac{1}{8}$ in. thick, can be simply butted together for welding. Above this thickness, however, it is generally advisable to bevel or vee the edges to be joined, double veeing on thicker material being advisable.

It is important to use the correct size of blowpipe nozzle for the thickness of copper to be welded, and precaution must be taken to conserve the heat in the metal, otherwise a proper autogenous weld is not obtained. The areas adjacent to the actual weld position must be at a much higher temperature than with most metals and alloys in order to counterbalance the rapid transfer of heat through the copper. Preheating is in many instances necessary to fulfil this condition, and the use of asbestos is very helpful in conserving the heat.

A neutral flame should be employed as excess of acetylene leaves the welds porous, apparently through causing the molten metal to bubble, which offers greater contact with the surrounding atmosphere, increasing the tendency of the metal to oxidise. A suitable flux is necessary, and the use of borax for this purpose results in inferior welds. A proper flux should be obtained from a reliable source, and the same applies to welding rods.

A good-looking weld can be made with ordinary copper, but such a welded part or article could not be relied upon to give the optimum properties expected of all metal to-day. No responsible body would sanction other than deoxidised copper for the fabrication of welded copper work of importance. Deoxidised copper is slightly stronger, and has a greater resistance to some forms of corrosion than ordinary copper; but apart from these points, and its perfect suitability for welding, it is essentially the same.

Copper possesses many advantages and has a large field of application; it is, therefore, quite natural that welding should take an important place among the many methods of fabricating copper to form plant and equipment. In the textile industry, for instance, copper is used in the processes of dyeing, washing, bleaching, drying, printing, pressing, and calendering, and there are many uses for welding in connection with the necessary appliances and plant. Welding offers many advantages for copper used in chemical plant. The weld is of the same material as the parent metal, and this is very important from the point of view of eliminating galvanic or electrolytic corrosion which is at times most troublesome and serious.

A solid, pressure-tight welded job is a boon to processes where a slight entry of air would be very detrimental to the working of the plant and also to the product, and chemical and other industries have a great friend in copper welding. In regard to strength, good welds in deoxidised copper plates have given in the as-welded condition tensile strengths from 12·5 to 13·5 tons per sq. in. with 35 to 45% elongation, measured over a weld-metal gauge length of 1 in. Thus it is shown that the deposited metal has very nearly the same tensile strength as the rolled and annealed copper plate, which plate gives a tensile strength of about 14·5 tons per sq. in. Welds hammered whilst at red heat give even better results than those in the as-welded condition, and cold-hammered welds show a greater tensile strength than the plate material.

Superheating and Heat-treating of Grey Cast Iron

By J. W. Donaldson, D.Sc.

The physical properties of cast iron have been improved by the addition of alloying elements, by the adoption of the centrifugal process and, during more recent years, by superheating the cast iron, and by heat-treatment. In this article, results on investigations relating to the last two methods are discussed.

DURING recent years many important investigations and researches have been undertaken with a view to improving the strength, hardness, resistance to shock and wear, and other properties of cast iron. Processes have been developed for the production of irons in which the carbon and silicon, or both, are much lower than in ordinary irons, and in which the proportion of phosphide eutectic present is also lower due to a lower phosphorus content. These processes include the Lantz process developed by Diefenthaler in Germany and carried out in this country under the name of the Perlit process, the Thyssen Emmel process, which is also of German origin, and the process developed by Meehan in the United States.

Improvements have also been made in the physical properties of cast iron by the addition of alloying elements. Much has been written about the influence of special elements on grey cast iron, and it may be briefly stated that the most satisfactory results have been obtained by the use of nickel and of chromium, either alloyed separately or together. Such elements have not improved the strength properties to any marked extent, but hardness, resistance to shock and wear have benefited considerably. Another method of manufacture, which has had an influence on the properties of grey cast iron, is the centrifugal method of casting, whereby the molten metal is poured into a rapidly rotating mould, and where the centrifugal force distributes it towards the inner periphery of the mould so that a hollow casting is produced on solidification. Cylindrical castings, such as cylinder liners and piston-ring drums, produced by this method have enhanced properties.

Other directions in which investigations have been made to develop cast iron are by superheating and by heat-treatment and by the combination of both superheating and heat-treatment. The results which have been obtained indicate the possibilities which may result from such treatments and render the consideration of such methods of importance to engineers and metallurgists.

Superheating of Cast Iron.

It is many years since the view was expressed that metals and alloys, but more particularly alloys, on melting do not attain full equilibrium conditions, and that such conditions are only brought about by prolonged heating after melting or by superheating at some temperature above the melting point, the degree of superheat being measured by the range of temperature above the melting point. Some investigators showed that with cast iron by increasing the casting temperature there is a distinct decrease in the percentage of graphite in the casting, while others indicated that an increase in the graphite content is noted with rising casting temperature. In 1925, Piwowarsky[1] published an investigation on the influence of temperature on the graphite formation of cast iron. Experiments made with casting temperatures up to 1,800° C. indicated that the eutectic carbon content increases as the temperature rises to about 1,500° C., but heating above this temperature and up to 1,800° C. favours the formation of eutectic graphite. These results were obtained with an iron containing 4·01% carbon and 0·13% silicon, and similar results were obtained with iron containing 3·6% carbon and silicon 2·4%, excepting that the point at which graphite tended to form in preference to carbide was 1,400° C. From these results Piwowarsky concluded that every molten cast iron has a distinct temperature range, depending upon its composition, above which the iron tends to solidify as a grey iron, and he assumed the coexistence of two types of molecules in the molten condition to which were attributed a graphite-forming or carbide-forming influence according to the type of molecule which predominated.

In a second paper, Piwowarsky[2] published the results of experiments on a low silicon Swedish iron which showed that variation up to 1·5% graphite could be obtained by varying the superheating, and that, if the silicon was increased by 2·5%, the graphite in the same iron could be reduced to 0·2 to 0·3%. Annealing this iron, similar to blackheart malleable, was claimed to confirm the effect of superheating, a more finely divided temper carbon being obtained by heat-treatment after superheating at 1,400° C and casting at 1,200° C., than when the iron had only been heated to 1,250° during melting.

In 1927 an entirely different theory as regards to what happens when molten cast iron is superheated, and the influence superheating has on the structure and properties of the solidified metal was put forward by Hanemann.[3] He considers that, if it is assumed that the solidification of grey cast iron proceeds according to the iron-graphite system, and no change takes place in the combined carbon after solidification, a stable limit of saturation must exist for the carbide and must depend on the total carbon and silicon contents. If the combined carbon content is above this limit a certain amount of solidification must take place according to the cementite or iron-iron carbide system, but if the combined carbon equals the limit of saturation, solidification follows the iron-graphite system. It is also suggested that when grey cast iron is melted all the graphite does not at once pass into solution, but that minute flakes remain suspended in the liquid and only dissolve at higher temperatures. If the iron solidifies while the graphite flakes are still present, they act as crystallisation nuclei and produce relatively large graphite plates; but if the flakes are dissolved by raising the temperature no graphite nuclei are present, and the graphite separates out in a very finely divided state. Two opposed reactions are, therefore, taking place during superheating, one accompanied by decrease in the proportion of combined carbon due to the decomposition of the solid solution which is induced by the fine dispersion of graphite, and the other by an increase in the combined carbon owing to closer approximation of the system to equilibrium. The increase followed by a decrease in the combined carbon content of grey cast iron during superheating is accounted for without assuming any change in the molecular condition, as suggested by Piwowarsky.

1 E. Piwowarsky, *Stahl u. Eisen*, 1925, vol. 45, p. 1,455.

2 E. Piwowarsky, *Stahl u. Eisen*, 1925, vol. 45, p. 2,001.

3 H. Hanemann, *Stahl u. Eisen*, 1927, vol. 47 p. 693.

The degree of superheat must be sufficiently high, 1,500° C. or over, to dissolve all the graphite, and at the same time solidification must be sufficiently slow to allow of all the solid solutions present to become saturated.

A series of tests by Meyer[4] on ordinary grey cast iron of different grades superheated at 1,250°, 1,300° 1,350°, 1,450°, and 1,500° C., and cast at 1,250° C., showed that in all cases the condition of the graphite became more finely divided as the temperature of the superheat increased. In some of the irons a temperature range of carbide inversion was observed and the change was apparent in the structure. This work, taken in conjunction with that of Hanemann's, supports the theory of superheat put forward by the latter investigator and appears to be much more probable as an explanation than that put forward by Piwowarsky

The practical influence of controlling graphite formation by superheating reflects itself in the physical properties of the irons cast by such a process. Hanemann, in one of his papers, shows the tensile strength of cast iron to increase perceptibly by superheating at 1,500° C. Bardenheuer and Zeyen[5] investigated the effect of superheating on the structure and mechanical properties. These investigators subjected a number of cast irons of varying composition to three degrees of superheat, 1,350° to 1,380° C., 1,460° to 1,500° C., and 1,580° to 1,630°, for 15 minutes before casting. With irons where the carbon content was high 3·4% and silicon and manganese contents normal, superheating refined the graphite, and a marked increase was obtained in both the tensile and transverse strengths. Below 3% carbon, the influence of superheating produced a decided fall in the transverse strength and the deflection, and with low phosphorus and low sulphur irons the tensile strength dropped also. This was particularly noticed when the carbon fell as low as 2·8%.

The falling off in the strength properties is stated to be due to the formation of a fairly coarse dendritic structure interspersed with a graphite network, and in the case of the low phosphorus and sulphur irons the network tends to form as a finely divided eutectic, throughout which ferrite crystals are distributed. The authors accept the nucleus-forming theory of Hanemann, and explain the formation of the dendritic structure as due to undercooling of the graphite. They consider that on cooling, mixed crystals low in carbon separate first, and the remaining liquid becomes supersaturated in regard to graphite and decomposes in relatively coarse graphite and ferrite on solidification, and that low phosphorus and sulphur favour this form of solidification. They suggest that this adverse effect of superheating on low carbon cast irons can be minimised by assisting the precipitation of graphite, either by using a high silicon iron or by adding powdered silicon to the ladle.

Recent experiments by Hurst[6] with castings produced by the centrifugal process also showed the effect of superheating on the mechanical and physical properties. Superheating to 1,550° to 1,600° C. was carried out by means of coke firing in a crucible, and the properties of the resulting casting compared with castings from metal heated in a similar manner to 1,200° to 1,250° C. The tensile strength, stiffness as indicated by the modulus of elasticity, and Brinell hardness were found to be slightly higher in the superheated metal. The permanent set value and the stress/deflection value, however, were lower. It was also noticed that the superheated metal was much more unsound than that cast normally, and was without sign of chill, which was remarkable, as the silicon content dropped from 1·02% in the normal castings to 1·55% in the superheated castings. It was suggested that this indicated that the effect of superheating was towards the production of a greyer iron.

The influence of combining superheating of cast iron with heat-treatment has also been investigated. As already mentioned, Piwowarsky[7] annealed superheated iron at 900° C. and found a finer distribution of the temper carbon. The rate of carbide decomposition was not found, however, to be accelerated. Annealing at 800° C. produced no refining effect on the temper carbon but increased the rate at which graphite separated. Further work by Piwowarsky[7] was published in 1927, when a preliminary account was given of the results obtained by superposing on preliminary superheating the effects of alloying nickel and chromium with cast iron, and subjecting the solidified material to a special heat-treatment.

The object aimed at in this investigation, which was carried out on small melts in the laboratory, was to produce an iron mainly white by using the superheating process and controlling the solidification, and then to add nickel and chromium to it, and by heat-treatment to graphitise the alloy to obtain the primary carbon as finely divided as possible, and at the same time to produce a fine-grained sorbitic-pearlite ground mass. Two main series of experiments were made, one with a high carbon and low silicon iron, and the other with a lower carbon and higher silicon iron. In each series heats were made without nickel and chromium, with from 1 to 3% of nickel, and with 3% nickel and 0·5% chromium. Heat-treatment for the purpose of graphitisation was carried out at 925° to 950° C., and a further heat-treatment to produce a sorbitic ground mass by quenching in oil from 820° to 850° C., followed by tempering at 650° C. with oil quenching, and a final annealing at 450° C. to remove hardening stresses.

As a result of these experiments, some remarkable results were obtained in the mechanical properties. Transverse strengths of 80 to 100 kg./mm.^{2} were obtained in a sound bar, and these were increased by 10 to 30%, by the addition of nickel or of nickel and chromium, to 100 to 130 kg./mm.^{2}. The deflection of such material in the transverse test was two or three times that of ordinary pearlitic grey cast iron. Tensile tests on sound test bars were obtained up to 75 kg./mm.^{2} (47·6 tons per sq. in.) and had measurable elongations of 2 to 4%. It was also stated that although the Brinell hardness was 200 to 300 all the specimens could be machined as easily as grey cast iron. Micro examination revealed an exceedingly fine-grained structure, it being only possible to resolve the eutectic graphite at a magnification of 500 diameters, and the ground mass could only be occasionally resolved into fine granular pearlite.

In considering these values it has to be remembered that they are the best of a rather irregular series, regarded by the author as being due to unsound test bars, which in many cases showed piping on fracture. They were also obtained, as previously mentioned, from small laboratory melts, and melting was carried out in basic lined crucibles, and the materials used were of very high purity. Whether such results could be obtained with ordinary grey cast iron and cupola melting or even with special melting in open hearth, crucible, or electric furnaces on a commercial scale is doubtful; nevertheless, they show the possibilities that exist for improving the qualities and properties of cast iron by such treatment.

Heat-treatment of Cast Iron.

The extent to which cast iron has been heat-treated from a practical point of view has developed enormously during the last ten years. Heat-treatment is not only confined to annealing in order to soften or reduce casting strains, but has also extended to hardening by quenching followed in some cases by tempering in a similar manner to steel. Iron castings have also been subjected to carburising followed by heat-treatment with satisfactory results. All these types of treatment affect the physical properties of the iron and there have been many investigations undertaken to determine the best methods of procedure.

Low temperature heat-treatment or low-temperature annealing is applied to cast iron to remove strains which

4 F. Meyer, *Stahl u. Eisen*, 1927, vol. 47, p. 294.
5 P. Bardenheuer and K. L. Zeyen, *Die Giesserei*, 1929, vol. 16, p. 733.
6 J. E. Hurst, *Foundry Trade Journal*, 1930, vol. 43, p. 351.
7 E. Piwowarsky, *Proc. Inst. Brit. Foundrymen*, 1926/7, vol. 20, p. 166.

are produced by irregular cooling in the mould, and which do not reveal themselves until after the casting has been machined, and which may then result in warping to a greater or lesser degree. It was customary at one time to allow castings to remain in storage for a prolonged period to allow the strains to be relieved at ordinary atmospheric temperature. Such procedure was costly, owing to the time required, and investigations have shown that similar and better results are attained if the castings are partly machined and subjected to a low-temperature annealing for a period of a few hours. In carrying out such treatment it is necessary to control both the temperature and time of heating, if the properties of material are not to be adversely affected. Heating at temperatures below 400° C., for a period up to 24 hours, releases casting strains, and does not affect the strength and hardness of the material to any marked degree. With some irons the strength shows a slight increase with such treatment. As the temperature of treatment rises, however, and the nearer it approaches the critical range of the material the more noticeable is the loss in the strength and hardness of the material, especially if the time of treatment is prolonged. When the work of the various investigators is considered, it appears that the best results are obtained from this type of treatment with temperatures ranging from 350° to 450° for a period of from four to six hours.

High-temperature heat-treatment which is carried out at temperatures above the critical range of the material, is not only applied to release casting strains, but also to soften the material and to facilitate machining. Such treatment, which is of comparatively short duration, has to be differentiated from the heat-treatment or annealing which is called "malleablising," where small castings packed in ore are heated for two or three days to 760° and very slowly cooled. High-temperature heat-treatment is usually carried out by heating castings to some temperature varying from 700° to 900° C., depending on the nature and composition of the casting. The most satisfactory is usually just slightly above the upper critical point. If the best results of this treatment are to be attained slow heating to the required temperature is necessary, followed by a sufficient period at the temperature to ensure thorough heating, and then slow cooling for a period until the temperature has fallen below the critical range. The slow heating and cooling eliminates failures due to cracking, brought about by sudden changes in temperature, and the short time at the temperature of treatment prevents too great a change taking place in the physical properties and structure of the material. With such treatment, however, no matter how low the temperature or how short the period of treatment, if the temperature exceeds the critical temperature, there is a steady decrease in the hardness and strength, particularly the tensile strength. The transverse strength is usually not affected to the same extent, but there is a decrease in it also.

The result of such treatment eliminates hard spots and induces softness, which allows of much easier machining. The antifrictional properties are also improved by the softness, and there is a distinct improvement in the resistance of the material to impact and shock. High-temperature treatment also eliminates any crystalline brittleness which may exist, as well as releasing internal strains due to cooling and other causes. In the automobile industry there has been a large increase in high-temperature heat-treatment of grey iron castings during the last few years, which would appear to indicate the beneficial effect this type of treatment has on castings even though the strength and hardness may be slightly lower than in ordinary untreated castings.

The heat-treatment of cast iron in a similar manner to steel by heating at temperatures above the critical range, quenching in various media to harden, and following the hardening treatment by tempering, is becoming more widely used. To obtain the best results, iron of a suitable composition has to be treated, as grey cast iron cast in sand moulds under ordinary foundry conditions has little or no hardening properties, when heated and quenched in the manner of tool steel. A certain proportion of combined carbon is necessary if the iron is to harden on quenching, and this can only be obtained by chilling, by controlling the composition, or by alloying with special elements. The most satisfactory results have been obtained with chilled irons and with castings to which nickel or chromium or both have been added. The procedure of hardening is similar to that adopted when heat-treating tool steel, the material being quenched from 850° to 920° C. in water, oil, or air. Tempering at from 250° to 350° C. to produce a desired hardness may follow. The object of such treatment is to increase the hardness and resistance to wear, and is applied to such parts as combustion cylinders and liners for internal combustion engines, iron rolls, cams, and other castings where wear is excessive.

The extent to which such treatment affects the properties of cast iron is best seen by considering some of the recent investigations which have been carried out on this important subject. Guillet, Galibourg, and Ballay[8], in a paper in 1928, published the results of a series of tests on the martensitic quenching of nickel and nickel chromium cast irons with the Brinell hardnesses determined after various quenching treatments. They also considered the influence of the various elements, nickel, chromium, silicon, and manganese on the results obtained. Their results indicate that machinable alloy irons can be hardened by heating to 900° to 950° C., and cooling in air or an air blast according to the size of the casting, and by such a treatment the Brinell hardness is increased by over 50%. Irons with higher percentages of nickel and chromium have to be annealed at 650° for machining before being subjected to air-hardening at 900° C., but are very susceptible to the latter treatment. In a more recent paper[8] these investigators show that the effect of quenching irons containing 1 to 5% of nickel, and following the hardening treatment by tempering, is to increase the mechanical properties and particularly the hardness.

Hurst[9] has also carried out a series of tests on the physical properties of nickel chromium alloy cast irons after oil- and air-hardening. Three irons were experimented with, containing 1·32% nickel, 0·44% chromium; 2·56% nickel, 0·95% chromium; and 3·37% nickel, 0·61% chromium, respectively. These irons were cast in the form of cylinders by the centrifugal process, and the first two were oil-hardened from 850 to 875° C., and the third air-hardened from 875° C. They were then tested for strength and hardness as cast, after hardening, and after tempering at various temperatures to 500° C.

As a result of these tests it is shown that the Brinell hardness values are increased substantially over those in the "as cast" condition by the hardening treatment, and the hardness of the hardened material is diminished by tempering—the higher the tempering temperature the lower the hardness value. There is a considerable falling-off in the tensile strengths of the various irons due to hardening both by oil and air, but a noticeable recovery in the strengths follows tempering the hardened materials. The modulus of elasticity is found to be slightly less in the hardened condition than in the "as cast" condition, but shows a recovery after tempering. The area included by the stress/deflection curves is influenced in a similar manner to the tensile strength, and the curves show that the material in its hardened and tempered condition is stiffer and attains a more truly elastic condition almost up to the breaking point. It is also stated that the best strength properties are developed after a hardening and tempering treatment at a temperature of 375 to 385° C., and that quantitatively the strength properties are slightly better in this condition than in the original cast condition. The structure of the hardened and tempered material is principally sorbitic.

8 L. Guillet, J. Galibourg, and M. Ballay, *Comptes Rendus*, 1928, p. 14; 1930, p. 528
9 J. E. Hurst, *Foundry Trade Journal*, 1930, vol. 43, p. 385.

Further experiments by Hurst[10] have shown that in suitable thin sections, plain unalloyed cast iron is capable of being hardened by oil-quenching from suitable temperatures, and plain chromium irons can be hardened in a similar manner without the presence of nickel, a higher level of hardness being obtained than in the nickel-chromium iron, and the hardening effect is more stable on tempering. In thicker sections, however, unalloyed cast iron is not very susceptible to oil hardening, the presence of nickel and chromium being necessary. It is also stated that a high hardening temperature of 920° C. is accompanied by definitely inferior results, and that the best results are obtained with the lowest possible quenching temperature. The addition of over 2% of manganese to iron containing 1·0% of nickel and 0·57% of chromium confers distinctly air-hardening properties as well as oil-hardening properties. The effect of quenching in molten salts at 150° C. is accompanied by a slightly higher strength value after hardening and prior to tempering, and a slightly lower hardness value.

In a recent American paper by Shore[11] the results of a series of tests on the hardening of grey cast iron are also dealt with. Chilled cast bars with a scleroscope hardness of 78 at the chill and 50 at the core were heated at 995° C. for three hours and allowed to cool, when the hardness of the chill was found to be 35. Reheating, however, and quenching in water produced a uniform scleroscope hardness of 78 throughout the bar. Somewhat similar results were obtained with an iron containing 4·50% nickel and 1·5% chromium, excepting that this did not soften perceptibly on the first treatment. A nickel cast iron containing 2·7% carbon, 1·71% silicon, 2·42% nickel, on quenching in water from 785° C. hardened from 70 to 80 scleroscope hardness. The hardness was uniform throughout and there were no signs of cracking or growth. A transverse strength of 4,500 lb. was obtained in this condition, which increased to 15,000 lb. on tempering at 320° C., when the scleroscope hardness became 60.

Consideration of these various results will indicate the advantages which would be gained in various branches of engineering practice by the adoption of such methods of treatment. In the motor-car industry their adoption has been more general than in many others, but as such methods become more widely known it is anticipated that their use will extend rapidly.

In addition to the already described methods of heat-treatment, iron castings can be subjected to casehardening, and in many cases small parts for machinery manufactured in cast iron are carburised for four hours at 920° to 950° C., cooled, reheated to 780° to 800° C., and quenched in brine, and finally tempered at 250° to 300° C. Such treatment enables the material to resist wear and impact. Special cast irons are also manufactured for treatment by the recently developed nitriding process of hardening. An alloy cast iron of a composition within the requirements of the commercial product Nitricastiron, containing 1.69% of chromium and 1.43% of aluminium has been tested by Hurst[12] on centrifugally-cast and sand-cast specimens in the "as cast," annealed, heat-treated, and nitrogen-hardened conditions. This alloy cast iron, which gives excellent strength properties, both in its cast and annealed condition, whether centrifugally or sand cast, is also susceptible to heat-treatment, and on treatment with ammonia gas under the conditions of the commercial nitrogen-hardening process, is accompanied by surface hardening and a diamond hardness value of 982 with a penetration of 0·18 in. The hardness and depth of penetration obtained are higher in the centrifugal-cast than in the sand-cast specimens, and the microstructures in each condition show coherence and freedom from spalling of the nitrogen-hardened surfaces.

10 J. E. Hurst, *Foundry Trade Journal*, 1931, vol. 45, p. 345.
11 A. F. Shore, *The Foundry*, 1930, vol. 58, p. 74.
12 J. E. Hurst, *Iron and Steel Inst.*, May, 1932.

Catalogues and Other Publications.

The development and application of Cindal corrosion-resistant alloys was fully described in a Cindal booklet published some time ago. It gave results obtained from cast aluminium alloys under conditions of exposure to atmospheric, sea water, and chemical uses. Tests have been continued with the object of studying those alloys which developed protective film-forming properties and we have received a copy of a booklet, which has just been published, giving data on a number of protective film-forming alloys that have now been produced. The investigatory work was carried out by Mr. D. R. Tullis, who also prepared the report which the booklet contains. Those interested should apply for a copy to Cindal Metals, Ltd., Rainhill, Liverpool.

We have received a twenty-four page pamphlet dealing with Edgar Allen—Allis-Chalmers Centrifugal Vibrating Screens, which are used for screening and sizing lump and granular materials, like crushed stone, ore, coke, and coal, etc., either wet or dry. The special features, together with facts and data, regarding these screens is presented in an admirable form. Copies are available from Edgar Allen and Co., Ltd., Imperial Steel Works, Sheffield.

The production, properties, and applications of aluminium are given in a 48-page booklet issued by the British Aluminium Co., Ltd. The quality of this publication is comparable with the many excellent booklets dealing with aluminium that have been issued by this company, and interested readers should apply for a copy to Adelaide House, King William Street, London, E.C. 4.

A modern but inexpensive high-speed and high-duty plate splitting shears, punch, and notcher is one of the productions of Henry Pels and Co., Ltd., 32-40, Osnaburgh Street, London, N.W. 1. Information regarding this machine is contained in List M 1932, which can be obtained on application to the Company.

The "Panalumin" processes provide a simple, cheap, and effective means for treating aluminium and magnesium alloys to protect them against corrosion, to colour, decorate, and prepare them for painting, lacquering, and electroplating. The Protective Coatings, Ltd., 7-8, Idol Lane, Eastcheap, London, E.C. 3, have published an informative booklet on the subject.

A handbook for electric welders, which has been written with the object of providing the welding operator and user of electric welding processes with information on the principles involved, has been published by Murex Welding Processes, Ltd., Ferry Lane Works, Walthamstow, London, E. 17. It contains 75 pages of useful data and information on electric welding. A series of short practical instructions for different types of work is given, and line illustrations assist in making the handbook valuable.

A new kind of alloy-steel booklet has been published by the United Steel Companies, Ltd. In its earlier pages attention is directed to the effects and uses of various alloying elements. The booklet gives comprehensive data on each steel, its composition, and specifications filled. An interesting feature is the relative prices indices given for the various steels. Although these can only be approximate, they will be found useful as an indication of the relative cost of various steels regardless of any changes in the general level of prices. The basis of the price indices is a 0·4% acid carbon oil-hardening steel, in the billet form, which is taken as 10. Another interesting feature in this publication is a consideration of the effect of mass upon physical tests. Copies of this publication may be obtained by responsible users from the United Steel Companies, Ltd., Dept. 14, 17, Westbourne Road, Sheffield.

We have received a very imformative catalogue of Swedish stainless and acid and heat resisting steels from Uddeholm General Agencies, Ltd. These steels are the products of Uddeholms Aktiebolag, a company which is one of the most comprehensive industrial enterprises in Sweden. This company manufacture stainless and acid and heat resisting steels for constructional and edge-tool purposes. Various grades of these types are discussed. Those interested should apply to 111, New Street, Birmingham, for a copy.

Institute of British Foundrymen

Twenty-ninth Annual Meeting at Newcastle-on-Tyne.

DESPITE the depressing condition of trade, large numbers of foundrymen from various parts of Great Britain attended the annual meeting and conference, held in the Lecture Theatre of the Literary and Philosophical Society, at Newcastle-on-Tyne, on June 8–10. The conference was preceded by a general council meeting, held on the evening of June 7, at the Royal Station Hotel.

At the opening meeting a civic welcome was extended to the members and their ladies by the Deputy-Lord Mayor, Councillor John Crosby, who said that Newcastle was honoured by the visit of so important an organisation, which embraced one of the basic industries. Supporting the Deputy-Lord Mayor were the Sheriff, Councillor John Leadbitter, Sir Arthur M. Sutherland, representing local industry, and Sir William Marris, Principal of Armstrong College, representing the technical educational activities of the district. At the conclusion of the civic welcome the Deputy-Lord Mayor, on behalf of the Institute, presented the Oliver Stubbs gold medal to Mr. J. E. Hurst, of Sheffield. This honour has been conferred on the recipient for his extensive and conspicuous work in alloy cast irons.

A brief business meeting followed, at which Mr. Andrew Harley, the immediate past-president duly installed Mr. Victor Stobie as president for ensuing year. Other officers appointed included Mr. C. E. Williams, of Cardiff, senior vice-president; Mr. Roy Stubbs, of Manchester, junior vice-president; while ex-president Harley was appointed a trustee in place of the late Mr. Oliver Stubbs. The election of members for council vacancies resulted in the appointment of Messrs. A. Campion (Scottish Branch), F. J. Heming (Birmingham), B. Hird (South Wales), J. R. Hyde (Sheffield), and J. M. Primrose (Falkirk). At this meeting five diploma awards were announced for the highest attainment in papers presented to the various branches during the session just completed. These were earned by Messrs. T. R. Twigger (Birmingham), Walter West (Lancashire), W. Y. Buchanan (Scottish), Dr. Guido Vannetti (London), and Dr. H. W. Swift (West Riding).

In his presidential address Mr. Stobie referred to one branch of the foundry industry which, notwithstanding past accomplishments, had a wide open field in front of it. He alluded more particularly to ironfounding, and suggested that the industry should adopt more exhaustive scientific investigation of cast iron, as, in his opinion, progress would result. He contended that metal is no longer a mystery, and those who investigate and explore its possibilities successfully will facilitate progress.

At the conclusion of the business meeting a technical session was held at which two papers were presented. The first of these, entitled "Some Notes on Moulding and Pouring Practice," by Mr. J. Pillon, was presented on behalf of the Association Technique de Fonderie, and in the absence of the author was introduced by Mr. V. Faulkner. The second paper, on "Quantity Production of Grey-iron Castings," was introduced by the author, Mr. J. O'Sullivan. These and other papers presented at the technical session held the following day are given in the following abstracts, together with brief reference to some of the discussions which resulted from them.

Introduction to the Study of Moulding and Casting.

In a foreword of this French exchange paper on the above subject, Mr. J. Pillon, the author, states that this thesis is not intended for beginners, and it assumes the possession of a sufficient scientific training and a practical acquaintance with the art of the standard required for admission to the Paris Foundry High School. It does not aim at initiation—its object is higher; it constitutes the first stage of a generalisation which the future will develop.

The paper comprises extracts from lectures given at the Paris Foundry High School by the author, and includes 135 line illustrations. The paper begins in rather an elementary fashion, but becomes more complex as it proceeds. A brief introductory discusses moulding in general, and in Part I. the author states that the problems presented in the whole question of moulding are of two different natures—the problems of moulding, properly so-called, and the problems of metallurgy. While it is recognised that both classes of problems demand simultaneous solution, the analysis given in this paper is limited to what is concerned with moulding and casting.

The fact that a mould can be prepared and metal cast into it in many different ways is appreciated, and, in the opinion of the author, this is perhaps the reason why there has been a total absence of theory until recently. It is asserted that by means of what are called "parameters of moulding" the moulder can be guided in the investigation of the methods of moulding, so that he will choose amongst all those available. A parameter is a constant term for each particular case considered, but which can take all possible values from one case to another.

It must be understood that it is not a question of establishing rules for the method of the moulding of a given casting within intangible limits, but by a methodical examination of the parameters, of deducing the solution or solutions which satisfy the maximum number of them. It is proposed, in this way, to put in a logical form which can easily be assimilated things which could formerly only be acquired by long years in the shops, which formed one of the greatest obstacles to the scientific evolution of the trade.

Excluding the metallurgical parameters the following are cited for pure moulding:—The selling price; the size of the castings; the importance of order from the point of view of quantity; the maximum simplicity in moulding; the tolerances imposed; the delivery period imposed; the soundness of metal and ease of moulding; the skill of operatives, and the materials available, etc.

In Part II. the author deals with static and dynamic forces exerted by molten metal on moulds and cores. After considerable explanations, assisted by many very difficult and complex illustrations, he concludes that the study of the static and dynamic effects has made apparent the forces and couples which have to be resisted by moulds, core, and projecting parts. It is obvious, he states, that sand alone, even when dried, cannot be expected to withstand these. Thus the solidity of the structure can only be ensured by the use of reinforcements, such as grids, judiciously planned and calculated in accordance with the methods employed in the study of the strength of materials, joined together or placed one over the other and secured to the box and to anchorages.

Copies of this paper were only available on the morning of the session at which it was presented, and Mr. Faulkner, in apologising for the delay, stated that the translation, coupled with the large number of blocks required for the illustrations, presented a stupendous task. Messrs. J. S. G. Primrose, C. E. Williams, E. Longden, F. W. Rowe, as well as the President, took part in the resultant discussion, but it was obvious that there had not been time to consider the practical value of the thesis.

Quantity Production of Grey-Iron Castings.

The successful production of castings on a quantity basis depends upon the adoption of proved methods that are applicable to the type of castings produced, but it is on the synchronisation of these methods that success is largely dependent. In the development of processes for the production of castings on a quantity basis the foundries of Messrs. Henry Ford and Son represent outstanding examples, and in a paper J. O'Sullivan concentrated on the sequence of operations which has been developed at the Cork Works. A chart illustrates the synchronisation employed, which indicates the importance of correct planning to obtain successful production.

Chart indicating the need for synchronisation in quantity production

In these works all raw materials are inspected by the laboratory; the bulk materials, such as pig iron, coke, scrap, sands, clays, are loaded in bins, whilst less bulky materials are put in stores. A night gang prepare the cupolas for the next day, and part of the charging gang start work an hour before the moulders. Charging is done by hand in the following sequence: Coke, limestone, steel, pig iron, borings, scrap, and ferro-silicon. The cupolas are kept level until sufficient charges have been made to complete the day's work. Charges are weighed by means of a large-dial type of spring balance.

The composition of the different charges, and the number to be made per hour is supplied by the laboratory. Pig iron transported to the charging door by conveyer, the scrap and limestone by crane, and the coke from overhead bunkers. The cupolas are fitted with volume-recording and pressure gauges, and once the blast is put on the furnace it is run to a determined capacity. The composition of the iron is specified at T.C. 3·0, Si 3·0, Mn 0·2, S not over 0·1, and P 0·04%. Silicon determinations are made hourly, whilst complete analyses of all metals are made at least once daily. The laboratory controls the temperature at which the metal is poured. The first tap of iron is invariably pigged, together with any surplus, into a pig-casting machine-conveyer, which returns it up to the charging floor. The liquid metal is conveyed by a monorail from the cupola spout to the various pouring stations.

Three kinds of sand are used as raw material in the core shop, a sharp sand or sea sand, a bank sand, and a small amount of recovered core sand. Core wires are eliminated to a considerable extent by the use of a core mixture, bonded with a soluble starch compound and dextrines, to which a small portion of oil is added for storage purposes. All cores are made in metal boxes, which are accurately machined, as also are the core-plates and shell-carriers. The making of cores is split into several operations, depending on the class of core, and as each core is made it is sprayed or dipped and placed on a green-core conveyer. Great care is devoted to the mixing of core washes, and one man mixes and maintains the stocks. All washes are kept agitated when in use; they must conform to certain Baumé numbers, usually 23·45, and their correctness is frequently checked by the foreman, as well as the man making the wash.

The moulding department consists of a jobbing shop, where patterns and the general equipment used in the plant are made, and three conveyer systems—two of the drag and one of the reel type. One of the drag conveyers, on which the large tractor castings are made is equipped with power-jolt roll-over machines, and its capacity is upwards of 2,800 moulds in eight hours. It operates as follows:—On the outside of rails which run in the direction of the pouring stations the drag or bottom half of the mould is carried slowly forward, and the men engaged on core-setting place in the cores and gauge them. By this time the mould has reached the position where the cope or top half of mould is made and finished ready to close and complete the mould. The mould is then closed, clamped, and heads made up by the time the pouring station is reached, metal is poured and mould is transferred to the centre set of rails, which travel in the opposite direction to the outside sets. The moulds are taken down to the shake-out, where a chain conveyer conveys the castings to the cleaning department. The sand is tempered and the flasks are returned to the machines.

The reel system comprises two pendulum-type mould conveyers, with an accompanying sand system with a capacity of 4,800 moulds in eight hours. The machines used are of hand roll-over and power-jolt squeeze and strip type. The number of men working in a team on the reel is smaller than on the drag, usually between 4 and 8, depending upon the type of machines in use. The system at work is as follows:—The man working upon the drag makes the mould, rolls it over on a revolving stand, which turns one-quarter of a revolution and also brings an empty flask directly to hand. The second man places in a core, if called for, and puts drag half of mould on to the reel. He also places the empty flask on the stand ready for the moulder and has the bottom board handy. The third man makes cope moulds and places them on a similar stand ready for the fourth man, who cleans out runners, completes operation by closing the mould, putting on mould weight, and checks the number made. The mould is then cast and shaken out, and flasks are hung on the conveyer. The castings are then inspected and placed on the casting conveyer for transport to the cleaning department.

When the castings have passed the core knock-out, they are loaded in tumbling barrels and tumbled. They are once more inspected and defective castings are sent to salvage department. Good castings travel on conveyers to be ground. If they have to be chipped then men with air-chisels standing at each side of conveyer do necessary operations. Castings that require it have their core wires extracted and are then hydraulically tested and finally inspected.

All scrap that arises during the course of manufacture has to go through salvage department, where it is sorted out and numbered according to a corresponding number on the scrap report for the various defects, and placed in their respective pile and painted. This also includes scrap returned from the machine-shop for foundry defects as well. Each morning all the foremen meet and examine the scrap pile. Reasons for its existence are agreed upon, and the steps to be taken to eliminate the causes are discussed. In addition, if the inspector at the shake-out picks out a defective casting, he immediately acquaints the foreman on the line, and core-room foreman and man in charge of pouring the metal are brought together on the job, if necessary. Defective castings that can be salvaged

are put through the reheating furnace, welded, and then either passed or finally scrapped. No scrap is accepted on the charging floor unless painted.

Several members asked for information regarding the limits in the composition of iron, and many commented on the small percentage of phosphorus. Apparently, Mr. O'Sullivan is not so much responsible for the metal mixtures as for the mould production and casting at the Cork Works.

Hardening Cast Iron.

Hardened and Tempered Cast Iron and Nitrogen Hardened Cast Iron.

Recent experiments by Mr. J. E. Hurst, published in papers given before the Sheffield Branch of the Institute of British Foundrymen, have shown that cast iron of suitable composition, heat-treated in a suitable manner, can be hardened and the strength properties improved. The important discovery arising out of these experiments is that the hardening effect brought about by the rapid cooling from temperatures above the upper critical point in all the materials examined is accompanied by a deterioration of the strength properties. This deterioration of the strength properties is immediately restored by tempering, and for each of the materials examined there exists a tempering temperature at which the strength properties are restored to a value exceeding those of the original material in the "as-cast" condition. Thus by suitable hardening and tempering a definite improvement in the

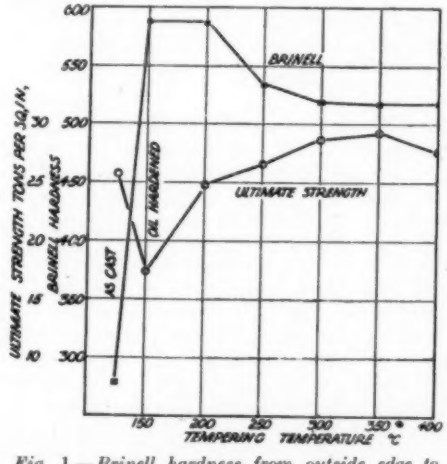

Fig. 1.—Brinell hardness from outside edge to centre of 1·75 in. dia. bars, with varying nickel contents (hardened condition).

strength properties can be obtained. In Fig. 1 a graph is drawn which is typical of the experimental results obtained and shows diagrammatically the effect of hardening and hardening and tempering on the Brinell hardness, and ultimate breaking strength. Attention has been paid to the brittleness property in addition to the ultimate strength in the experimental work already carried out. The resilience value, the reciprocal of brittleness, behaves exactly as the ultimate strength, and a definite improvement in this value is obtained, due to hardening and tempering.

The conclusion drawn from these experiments indicated that, in suitable thin sections, plain unalloyed cast iron is capable of being hardened by oil-quenching from suitable temperatures. In like manner, plain chromium irons, plain copper irons, and aluminium-chromium irons, are capable of being hardened, and the presence of nickel is not necessary to obtain the hardening effect. In suitable thin sections the plain chromium iron appears to be accompanied by a higher level of hardness values than the nickel-chromium iron, and the hardening effect is more stable on tempering.

In all cases the effect of hardening is accompanied by a loss of strength properties, and in all cases these are recovered and reach a value definitely higher than the "as-cast" value after tempering. The behaviour of the various cast irons tested in respect of modulus of elasticity, after hardening and tempering, is somewhat irregular; on the whole, this value is not very greatly changed.

In thicker sections it was shown that an ordinary cast iron is not very susceptible to hardening by quenching in oil. The presence of the alloy constituents nickel and chromium increases the hardening capacity. In the thicker sections nickel has the effect of increasing the depth of penetration of the hardening and appears to have the effect of increasing the degree of hardness obtainable. A high hardening temperature of 920° C. was accompanied by definitely inferior results both as to hardness and strength values in the samples experimented with after hardening and tempering. The lowest quenching temperatures tend towards the best results.

The effect of quenching in molten salts at a temperature of 150° C. in the case of the samples investigated was shown to be accompanied by a slightly higher strength value, and a slightly lower hardness value after hardening and prior to tempering.

Some further experiments of a more comprehensive nature have been carried out since, and in this paper Mr. Hurst presents these further results in full. The object of these experiments was to examine further the effect of

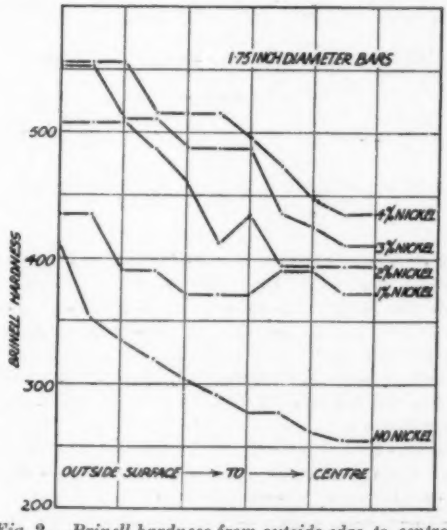

Fig. 2.—Brinell hardness from outside edge to centre of 4 in. dia. bars, with varying nickel contents (hardened condition).

hardening by oil-quenching specimens of increasing thickness and to ascertain the influence of increasing nickel contents on the results obtained. Five sets of bars were cast; the first set in a plain chromium iron and each successive set with the addition of 1, 2, 3, and 4% of nickel to the material. The sets consisted of round bars, $1\frac{3}{4}$ in., 4 in., and $5\frac{1}{4}$ in. in diameter, and about 20 in. long. The chemical analyses of these bars in the "as-cast" condition are given in the paper.

The Brinell hardness of the bars on a polished flat surface immediately under the outer skin in the "as-cast" condition, shows that, with increasing nickel contents, the hardness is lowered, until with 4% nickel, approaching the martensitic range, the hardness increases. The effect of the increased diameters results in slower rate of cooling and in a lowering of the hardness values.

The bars were subjected to a uniform annealing treatment at 900° C., and Brinell hardness results indicate that in all cases the annealing treatment reduced the hardness. Apparently nickel tends to maintain a slightly higher level

of hardness in the central portions of the larger diameter bars. After the annealing treatment the bars were hardened by quenching in oil from a temperature of 875° C., and further hardness determinations carried out are plotted in diagrams, Figs. 2, 3, and 4. These diagrams show the hardness results obtained on the different nickel-content bars for each diameter of bar, and demonstrate very clearly the valuable property of nickel in cast iron suitable for hardening and tempering.

In some notes on the operations of hardening and tempering, the author stated that the procedure followed and the precautions to be taken with cast iron are identical

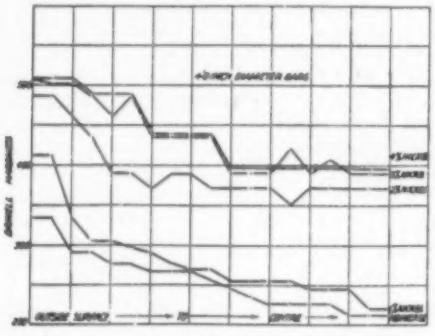

Fig. 3.—Brinell hardness from outside edge to centre of 5.5 in. dia. bars, with varying nickel contents (hardened condition).

with those for steel parts. More perfect success is ensured by the adoption of some preliminary treatment. Two types of treatment are available, the first being an annealing treatment, in which the castings are heated to a temperature of 825° to 900° C., followed by slow cooling in the furnace. The second is referred to as a stabilising treatment, such as is adopted in the nitrogen hardening process; the temperatures recommended for cast iron are from 450° to 600° C. The author describes an experiment undertaken to examine the effect of drastic annealing of the casting on the hardening and tempering properties. It is shown that excessive annealing is accompanied by considerable loss of combined carbon, and further that it may be accompanied by serious deterioration in strength of properties.

The nitrogen-hardening of cast iron was discussed by the author, who stated that the best results obtained so far have been with a cast iron alloyed with aluminium and chromium. The chemical composition and properties of aluminium-chromium cast iron suitable for nitrogen hardening have been described by Mr. Hurst in a recent paper before the Iron and Steel Institute.

In presenting his paper Mr. Hurst stated that further work on the subject was in progress. Already castings of varying degrees of complexity are hardened and tempered successfully. Mr. Lambert commented on the quenching of cast iron and the difficulties involved. Mr. Rowe asked whether any accelerating process was used for hastening case-hardening. Dr. Everest desired information on the influence of nickel and chromium on heat-treatment of the cast iron. Practical support for the value of the work carried out by Mr. Hurst came from Mr. Hudson, who cited an instance in which a part in a valve gave considerable trouble as a result of erosion. Following results of investigations by Mr. Hurst, however, a heat-treated part had overcome the difficulty. Mr. Hurst recognised that quenching presented difficulties, but up to the present the castings treated had been relatively small. He had not tried accelerators for case-hardening, and was not prepared to say what influence nickel and chromium had on heat-treatment; experiments were in progress which he hoped would give data of value later. He thanked Mr. Hudson for his remarks.

High-Test Cast Iron.

In this paper Mr. R. S. Macpherran discusses the present status of high-test cast iron in the United States of America and only those cast irons having a tensile strength greater than 20 tons per sq. in., from test specimens machined from the old standard A.S.T.M. arbitration test-bars, are included. There is no standard for high-test iron, and no specifications covering recent developments; foundries therefore adopt the material and practice best suited to their own needs. During the last few years there has been a marked tendency toward specialisation. This specialisation has been assisted by the great production demand of

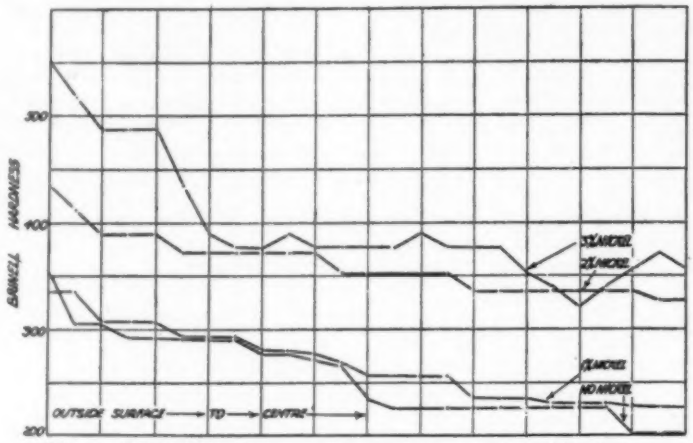

Fig. 4.—Effect of hardening and tempering on the Brinell hardness and ultimate breaking strength of cast iron.

the automobile industry and by the development of the electric furnace. It is of interest to note that over eighty electric furnaces are reported to have been installed in the U.S.A. for the production of commercial iron castings.

In general, high-test cast iron is made by one of the following processes:—Electric furnace (with or without duplexing from the cupola); air furnace (with or without duplexing from the cupola); and cupola. The author, in dealing with these processes, gave a few specific and typical cases where high-test cast iron is being successfully made and used. One firm specialising in automobile cylinders and heads, uses a 3-ton electric furnace. Iron melted in a 48-in. cupola is tapped into this furnace at intervals. Scrap iron comprises the bulk of the charge, with between 20 to 30% of bundled sheet steel added in the electric furnace. The materials used and the operation costs of this duplexing process are low, and tests on two arbitration bars gave the results shown in table I.

High impact value and additional refinement of grain are claimed for this iron, due to superheating in the furnace.

Another firm specialising in brake drums charges electric furnaces with cupola iron and adds sufficient steel to produce a white fracture, and proper carbon content and graphite in the ladle. The tensile strength of this iron ranges from 22·3 to 26·7 tons per sq. in., and the approximate analyses are as follow:—C.C., 0·50 to 0·70%; Gr., 1·80 to 2·00; Si, 2·10 to 2·40; Mn, 0·30 to 0·50; S, 0·09 (max.); P, 0·20 (max.); Mo, 0·40 to 0·60%.

Specialising in camshafts for automobile work, a company uses electric furnace iron. The camshafts are not heat-treated, but are made with or without a chill as desired. Typical figures from arbitration test-bars show 6,000 lb. to 7,500 lb. transverse strength over 12-in. supports, a tensile strength of 24·5 to 26·7 tons per sq. in., torsion equal to that of camshaft steel, and the iron gives remarkable wearing qualities.

Air furnace processes also facilitate the production of low-carbon cast irons, and in some cases air furnaces which are mainly in use for malleable iron castings are now using their excess capacity for making high-test iron. Tensile strengths of 26·7 to 49·1 tons per sq. in. may be obtained

with various elongations up to 15%, depending on the heat-treatment. In one heat-treatment castings and test-bars were heated to 926° C., at which they were held for 20 hours and then cooled in air, reheated to just below the critical temperature and held 20 hours, then cooled in air. The chemical analysis of this iron showed 2·29% carbon, 1·11 silicon, 0·85 manganese, 0·089 sulphur, and 0·18 phosphorus; its physical properties showed a tensile strength of 33·4 tons per sq. in., 14% elongation in 2 in., 18% reduction of area, and a Brinell hardness of 179.

TABLE I.

CHEMICAL ANALYSES OF NICKEL-CHROMIUM CAST-IRON BARS WITH VARYING NICKEL CONTENT.

Sample No.	T.C.	C.C.	Gr.	Si.	Mn.	P.	Ni.	Cr.
1	3·71	0·57	3·14	1·92	0·96	0·45	Nil	0·11
2	3·76	0·41	3·35	1·97	1·02	0·48	1·18	0·11
3	3·71	0·43	3·28	1·92	0·96	0·47	2·05	0·11
4	3·71	0·36	3·35	1·92	0·99	0·49	2·97	0·15
5	3·71	0·43	3·28	1·97	0·94	0·47	4·10	0·15

Bar No.	Transverse Load in Lb. (12-in. Supports).	Deflection in In.	M.S., Tons per Sq. In.	Brinell Hardness.
1	5,430	0·17	24·0	248
2	4,850	0·15	21·6	241

The analyses of the bars gave:

	Bar No. 1.	Bar No. 2.
T.C.	3·02	2·94
Si	2·36	2·41
Mn	0·82	0·85
S	0·086	0·079
P	0·13	0·17
Ni	0·44	0·50
Cr	0·37	0·31
Mo	0·58	—

Mention was made of Meehanite and Ermalite high-test irons, the former being made in the cupola, air, or electric furnace, and the latter in an air furnace; both are produced by patented processes.

The author recorded his own experience with the cupola in which a high percentage of steel is charged, with a low percentage of pig iron, with ferro-silicon and ferro-manganese additions in the cupola, leaving only a small amount of ferro-manganese-silicon to be added in the ladle. The addition of nickel or molybdenum facilitates machining, increases Brinell hardness, and adds to the strength of the iron. In practice the author adds 1% of nickel or 0·35% molybdenum, but he considers that 1% of nickel has more effect on the machining properties than 0·35% of molybdenum. It is reported that the continuous running of cupolas in which the charge contains 25% of steel, will result in 0·15 to 0·25% lower carbon product than when using the intermittent tapping process.

The author gives details of one example of producing the high-steel charge metal which has been in successful operation for over four years. In a 54-in. cupola the metal charges are 1 ton 6 cwts. 3 qrs. in weight, with 3·25 cwts. of coke between charges. The charge consists of from 4 to 5% of 50% ferro-silicon, 0·5% of ferro-manganese, 6 to 10% return high-test iron scrap, 5% pig iron, and the remainder steel. To each 1,000 lb. of molten metal 3 lb. of powdered ferro-manganese-silicon (silicon 50%, manganese 25%) is added. When the metal is used for castings with little or no machine work, no alloys are added. For small castings, with much machine work 1% of nickel or 0·35% molybdenum are added. Of 200 consecutive routine tests, the average tensile strength of irons made by this process was 24·9 tons per sq. in.

The author has made an effort to eliminate theory as much as possible, and to outline only operations in commercial practice, and the results achieved will prove of considerable interest to foundrymen in this country.

Several members joined in the discussion, and many commented on the remarkable results achieved.

Ferrous and Non-Ferrous Metals in the Foundry.

In the production of ferrous and non-ferrous castings there are so many points of similarity that the distinction between the two branches as it stands to-day is arbitrary, and not only unjustified, but unwise. This, briefly, is the opinion of Dr. W. Rosenhain, as expressed in a paper in which he considered the similarities and dissimilarities between the behaviour of ferrous and non-ferrous metals in the foundry. The line of demarcation which has grown up between these two branches, as far as the foundry is concerned, is primarily due to the fact that the production of sound castings is best assured by preparing and casting moulds in separate shops. This is not entirely due to the improved technique resulting from specialisation, though this is important, but to the need for separating the floor sand or that sand which forms the main part of each mould. Best results are only obtained when the sand is prepared and used only for the particular metal or alloys experience has shown to be best. But while foundries of each type are now generally considered as separate units, each has much to learn from the other, yet, in practice, there is at present little interchange of knowledge and experience between the ferrous and non-ferrous branches of the industry.

In tracing the main points of difference and similarity between the two groups of metals. Dr. Rosenhain referred to melting differences and the modification in plant necessary in relation to the initial cost of the metals and waste values. He discussed moulding sands, mould dressings, and core binders; made comparisons in running the different metals; and generally indicated that, from the technical point of view, the requirements of both branches are so closely allied that they should be pursued together.

An immense amount of research work both in laboratories and in foundries is being carried on, while industrial trials of various kinds are innumerable. If one compares the published literature of the two branches one cannot but be struck by the fact that there is a great amount of duplication which could be saved if those interested in both branches could be induced to work closely together. In this country, although the Institute of British Foundrymen covers both branches of the industry, some of our other very important organisations do not. There is in the first place the separation between the Institute of Metals and the Iron and Steel Institute, and there is also the separate organisations of the Cast Iron Research Association and the Non-Ferrous Metals Research Association.

The author does not suggest that these various organisations should be immediately amalgamated, but there is undoubtedly a large amount of common ground upon which duplication of effort could and should be avoided, and hopes that his brief review of this aspect of the subject may do something to help developments in that direction.

This paper embracing, as it did, a very wide field, much of which was of a controversial character, many members took part in a subsequent discussion. Messrs. Faulkner, Cooper, Bird, and Rowe showed considerable interest in the subject matter presented by Dr. Rosenhain, and the opportunity was taken to question him on a wide range of problems.

Some Lifting Consideration in a Jobbing Steel Foundry.

The amount of handling of material, equipment, and metal in relation to the weight of castings produced in the average foundry is very large; particularly is this true in the jobbing steel foundry. In dealing with this subject, Mr. F. J. Hemming states that in the foundry with which he is associated, data which has been prepared shows that 100 tons of material is lifted in the production of 1 ton of castings. Figures show that 75% of the lifting power is completed by the time the casting is handed to the fettling shop, and it is in the foundry where production economies should be made in the application of lifting power available.

It is not an easy matter to arrive at an analysis of lifting figures in the foundry, but the author has endeavoured through observation and data to divide the lifting power applied, and allocates 60% to the handling of sand and equipment and 15% to metal. In effecting economy, foundry layout and flexibility of lifts are of vital importance. Although no set of lifting conditions can ever be perfect for the jobbing steel foundry, if all difficulties experienced are carefully examined and steps taken to overcome them, each modification to ensure better handling facilities will assist in approaching more nearly to the ideal conditions. Each steel founder must solve his own difficulties in the light of his own experience. The author illustrates two improvements which have been the outcome of experience—the introduction of greater flexibility of lifting power in a heavy foundry, and a simple expedient to meet the requirements in a light foundry.

A Resume of the Work of the Malleable Iron Sub-Committee of the Institute's Technical Committee.

The Sub-Committee on malleable cast iron has collected as many as possible of the available specifications controlling the manufacture and inspection of this material. An examination of these specifications has shown generally that their foundation was governed by the British Standards Specifications (B.S.I.) Nos. 309 and 310. These specifications are dated November, 1927, and in view of improvements in manufacture, it was felt that the old specifications should be thoroughly examined, and, if necessary, suggestions for a new specification drawn up.

Discussion has shown the specifications to be unsatisfactory in the following directions:—

(1) The standard set is low, easily attained, and often exceeded by the manufacturer. It seems, therefore, that to make progress this standard should be re-examined, and possibly raised.

(2) A standard-sized test-bar is called for, and this cannot always represent various sizes of castings. It is quite definite in the manufacture of white-heart malleable that castings of different thicknesses must be annealed under different conditions, and therefore test-bars of a standard thickness, annealed with these different-sized castings, cannot give a true indication of the annealing of the batch they represent.

(3) The provision of three round and three flat bars for every batch of castings is irksome to the manufacturer, particularly when the quantity of castings ordered is small.

(4) The inspector must rely on the integrity of the manufacturer as to whether the test-bars are cast at the same time as the castings and annealed with them.

(5) The specification is not designed to cover castings suitable for electrical or magnetic induction purposes.

(6) The specification does not distinguish between castings for high- or low-grade work. In many cases, such as ironmongery, castings of lower specification, and hence cheaper material would be suitable, whilst castings upon which life depends, such as automobile work, require a different specification.

Many of these objections can be overcome. One suggestion which has been put forward by the B.C.I.R.A.[1] is to use a different-sized test-bar to represent various castings. The Association suggests the use of three sizes of test-bar—viz., 0·253 in., 0·564 in., and 0·977 in. dia. The two smallest to be used for white-heart and thin-walled castings, and the two largest to be used for black-heart and thick-walled castings. The smaller size has also been advocated by Stotz[2] and by Rémy.[3]

The Sub-Committee cannot agree to the generalisation, as set forth in the B.C.I.R.A. paper, that light castings are usually white-heart, and heavy castings black-heart, and, therefore, that the smaller test-bars be used for white-heart, with the larger ones for black-heart. Large outputs of heavy-sectioned white-heart are known, and also black-heart less than one-eighth of an inch in thickness. Therefore, it is felt that the same range of test-bars should be used for both types of malleable.

Other problems also suggest themselves, such as the decision as to the size of bar to be cast, the position of the bar for annealing, whether more than one bar shall be cast in the case of widely varying sections, and, if so, how far the results on one shall affect the interpretation of the others.

These recommendations are definitely progressive, and the Sub-Committee feel that by first investigating the correlation of microstructure with strength they will be furthering the work and collecting information which should be useful in compiling final recommendations.

The Sub-Committee intend to investigate an alternative in the shape of a standard bar with modified requirements. In regard to grades of malleable iron, recommendations are to be made in respect of agricultural castings; aircraft; automobile castings; colliery work; electrical work; engines; general ironmongery; lifts, cranes, conveyers, etc.; machine tools, textile machinery; railways and shipbuilding. Work is to be continued which is expected to lead to the creation of a specification which it is hoped will receive the support of the electrical manufacturers.

The properties of malleable cast iron may be materially modified by after-treatment, and it is felt that a micro-examination of the structure would provide a more valuable guide to the behaviour of the material under the heat than the mechanical properties. The Sub-Committee propose to correlate data results with microstructure in order to show the relationship between mechanical properties, microstructure, and behaviour under heat in a manner most helpful to the manufacturer and the user. It must be remembered that this Sub-Committee has only been in existence a short time, and under somewhat difficult circumstances considerable time has been taken up in finding a common outlook.

Contraction, Distortion, and Camber in Grey-Iron Castings.

All foundrymen will appreciate the complexity of the above subjects presented by Mr. E. Longden in an admirable paper. The phenomenon of distortion and irregular linear contraction in grey cast iron have been investigated on a laboratory scale, but apart from investigations on small and light castings, there has been no investigation of the causes and influences that hinder and mask ordinary contraction in large and complicated castings. The author suggests that since solid contraction operates in all types of castings, interest should be directed to the standardising of the physical means for counteracting unequal and restricted contraction, and the attendant abnormalities, rather than with the underlying theories and their causes. The striking lack of data and standards for camber allowances in castings, to which the author draws attention, is undoubtedly due to the realisation that definite rules and standards cannot be readily applied, any more than the so-called standard contraction rule. Modifications must be made according to the design, but the particular composition of the iron

(*Continued on page* 60.)

The Laws of Freezing and Crystallisation in Steel Ingots*

Traces of transcrystallisation can seldom be seen in cold carbon and many alloy steels. An investigation, undertaken with the object of clearing up whether the columnar structure was characteristic of such fractures, has been carried out on ingots which had been upset at varying times after casting and parted down the centre line, a summary of which is given in this article.

THE basis of our present knowledge of the processes of crystallisation, and the laws according to which it develops, were established by G. Tammann in a classical research (Kristallisieren und Schmelzen. Leipzig. 1903). Crystallisation is started by the spontaneous formation of nuclei in the cooling melt. He introduced the two fundamental conceptions of the grain number (K Z), and crystallisation velocity (K G). The main factor influencing these values was designated by him to be the temperature at which solidification or crystallisation sets in. In practice solidification does not occur exactly at the theoretical temperature, it is subject to various delays. According to Tammann, the degree of undercooling of the melt is also a measure of the forces which start crystallisation, and, consequently, also of the two grain factors, the number K Z and the velocity K G. The laws deduced by Tammann strictly only apply to fields in which the temperature is uniform, whereas one has, in practice, to deal with varying temperatures in the mould walls and also in the ingot.

These variations in temperature occur both between different parts of the ingot and with the elapsed time, going hand in hand with the progress of the crystallisation. Unfortunately, there are still no reliable measurements of the temperature distribution within the ingot during solidification.

As a broad generalisation it can, however, be said that due to the rapid transfer of heat to the mould at the first, moment of solidification, the skin layer is undercooled to such an extent that the number of nuclei K G reaches approximately its maximum value, and the crystallisation velocity K Z attains a very high value, whence this zone displays the well-known more or less equiaxed very fine crystallisation. The rapid reduction in the quantity of heat carried off by the mould, and the increase in the latent heat released by solidification, limits this condition of undercooling to a very short period. The undercooling is reduced and the speed of crystallisation K G begins to surpass the number of nuclei K Z. With larger temperature gradients columnar crystallisation (transcrystallisation) will predominate. To the extent to which the carrying-off of heat is still further abated and the temperature gradient diminished the undercooling will recede. The formation of more or less equiaxed crystals will then prevail.

The great importance which attaches to the development of the ingot structure, in connection with the possibility of working the finished steel and the properties of the latter, has occasioned a number of recent distinguished investigations. Whilst rapid methods have been developed for examining a number of properties, due to the metallurgical process, the chemical composition and treatment of the steel, the derivation of reliable indications for those properties which are based on the progress of solidification presents very considerable difficulties. Some of the factors influencing the solidification have been examined among others by W. J. Priestley, F. Loitner, F. Bardenheuer, and the Committee on the Heterogeneity of Steel Ingots.

Whilst the simple cold fracture of nickel-chrome steel ingots renders visible the structure of the material, it is but seldom that traces of transcrystallisation can be seen in similar fractures of carbon and many alloy steels. It is, however, well known that such columnar crystals can often be observed in hot fractures.

In order to clear up the question whether the columnar structure was characteristic of such fractures, the author carried out experiments in which discs of about 25 mm. thickness were cut from ingots containing about 0·7 to 0·8% C., 0·15 to 0·25% Si., 0·2 to 0·3% Mn., 0·015% P., and 0·005% S.; these being fractured at a range of temperatures increasing from 100° C. These tests led to the surprising result that already at a temperature of 250° C.—*i.e.*, at a blue heat—the crystallisation became clearly apparent in the fracture.

This method of testing is simple, and can be rapidly carried out. A disc having a thickness of 15 to 25 mm. is cut in the lathe from the top and bottom of the ingot to be examined, raised to a blue heat and broken under the hammer. In order to facilitate fracture a 5-mm. notch can be cut across the disc. This blue-heat fracture test is the basis of the systematic investigation made of the influence of the solidification and cooling conditions on the progress of crystallisation of carbon steels cast into ingot moulds.

The investigation was carried out on ingots which had been upset at varying times after casting and parted down the centre line. A semi-circular annular piece was cut from these 30 mm. below the top rim, and another 100 mm. above the top of the radius of the bottom. These semi-circular rings were heated to a blue heat and broken under a steam hammer. The effects of the following factors were examined: (*a*) Casting temperature, (*b*) initial temperature of the mould, (*c*) casting speed, (*d*) size of ingot, (*e*) thickness of mould wall.

The progress of crystallisation was investigated on the following ingots, with different casting temperatures, etc.: (*a*) 200-kilog. ingots, 200-mm. dia., upset after 1, 2, 3, and 5 mins; (*b*) 350-kilog. ingots, 250-mm. dia., upset after 1, 3, and 7 mins.; (*c*) 700-kilog. ingots, 340-mm. dia., and 1,200-kilog. ingots, 440-mm. dia., upset after 1, 5, and 12 mins.

Exactly similar blue fracture tests were made with a steel containing 1·1% C.; the ingots being upset after 1, 3, and 5 mins. The fundamental crystallisation processes observed with the milder steel occurred in a similar manner with this hard tool steel.

Finally, a test was made under works conditions, the ingots cast from a heat being numbered consecutively. The casting temperature was the same, 1,400°C. uncorrected, for the first 21 ingots, and then dropped to 1,360° C. In the case of ingot No. 21 the columnar crystallisation could be followed almost to the centre, while ingot No. 22 was almost structureless. The same test was repeated with a 1% C. heat. The ingots up to No. 20 showed definite transcrystallisation, while in Nos. 22 to 25 the structure was completely broken down.

The effect of heating on the primary structure was examined by annealing a number of samples at 850° C. for one and two hours, from ingots upset at periods up to 5 mins. The results of these tests appeared to prove that the breakdown of structure observed as commencing during the progressive solidification of ingots was a result of spontaneous annealing during the slow cooling through the temperature zone above the transformation point.

* By Dr.-Ing. Bernhard Matuschka. Abstracted from *Archiv fur das Eisenhuttenwesen*, January, 1932.

The following conclusions were drawn regarding the development and changes in the structure of ingots of clean, well-deoxidised carbon steels :—

(1) Soon after solidification the ingot structure consists of elongated crystallites, with the principal axis in the direction of the flow of heat.

(2) The transcrystallisation (columnar crystals) extends throughout the greater part of the ingot section.

(3) This transcrystalline structure, due to the breakdown of the columnar crystals which sets in at higher temperatures, undergoes a progressive change, from the centre of the ingot outwards, into a fine-grained structure with small equiaxed crystals.

(4) The columnar crystals of the transcrystalline ingot structure were finer the lower the casting temperature.

(5) The breaking down of the crystallisation is more rapid and more complete the finer the primary structure, or the lower the casting temperature.

(6) The breaking down of the crystals can be restrained by quick cooling of the solidified ingot below the change-point. The suppression of the breaking down can be the better secured, the less the tendency of the crystals to split up—*i.e.*, the higher the casting temperature.

(7) Heating at high temperature causes renewed coarsening of the grain of the broken-down structure.

(8) Heating at temperatures above the change-point can cause breaking down of the transcrystallisation also in the outer layers after casting.

(9) Annealing above the change-point can still further complete the breaking down of the grain.

In examining the structure of a casting it is essential to distinguish between the primary or solidification structure and the secondary or transformation structure. The primary structure is built up of primary crystals, which consist of similarly orientated dendrites. It is mainly dependent on the composition and crystallographic nature of the steel and the conditions of freezing. The freezing conditions affect the undercooling, and with it the number of nuclei K Z and the crystallisation velocity K G ; further, the amount of the temperature gradient, and thereby the main direction of the growth of the crystals (transcrystallisation). The primary cast grain undergoes during cooling a more or less extensive breaking down and transformation into a secondary structure.

The apparently varying behaviour of the different alloyed and plain carbon steels in regard to the development of their ingot structures is thus explained. Above all, the differences in the cast structure can be referred back to the dependence on the temperature of the grain number and the crystallisation velocity, as also the differences in the latter in the directions of the principal and secondary axes. The development of the primary structure depends on the tendency to breakdown of the crystalline grains. In all cases the decisive influence of the casting temperature (undercooling) and of slow cooling, especially within the critical temperature range, remains a common characteristic.

In every case the finest possible primary structure should be aimed at as the starting-point for the subsequent working of the material. The means by which this can be appropriately secured are evident from the previous consideration. In the case of austenitic steels principal attention must be given to the working of the heat and to the casting temperature. For the other classes of steels, besides these factors, importance attaches to the position of the critical temperature range, and the tendency of the steel to breakdown of the ingot structure. Whilst in many cases it will be sufficient to give special attention to slow cooling after casting, or to careful warming-up before hot-working, in other cases special annealing of the ingot is necessary. The beneficial effect of good preheating of various alloy steels thus appears in a new light. The breakdown of the cast structure here exercises an influence, in addition to complete heating throughout the ingot. An insufficient soaking time can lead to failure with the same quality of ingot. On the other hand, differences in the cast structure, with the same soaking, can give rise to difficulties in hot-working. In conclusion, slight differences in the chemical composition can greatly affect the tendency to breaking down of the structure and, consequently, the working of the material.

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(*Continued from page* 58).

used, and the method of running the casting, also have an influence on the amount of camber likely to take place in a casting. Hard-and-fast rules, in our opinion, are an impossibility, unless every factor is under control, and experience in the production of castings likely to camber plays an important part in successfully overcoming the difficulties. An excellent camber chart is given in this paper, suitable for the heavier type of machine-tool castings, but we agree with the author in his statement that " no single condition or combination of conditions can be absolutely successful unless linked with an understanding of the principles underlying the conflicting phenomena of dual contraction and expansion common to grey iron."

As a result of some experimental work on the subject, the author has come to the conclusion that at a period some time after solidification the casting is slightly larger than the mould, and if the material composing the mould is strong enough to resist expansion and distension of the skin of the casting on cooling, or if the cooling of the outer envelope of the metal is accelerated so that a resisting wall of solidified metal is formed, then the energy released by the dissociation of carbon is returned as a force to compress the inner and progressively solidifying metal layers.

Special mould conditions can therefore be arranged which will reduce fluid shrinkage in grey cast iron to vanishing point, and at the same time produce a very dense structure in the metal generally. Thus, the contraction strains and stresses of grey cast iron are dual and very conflicting. Any considerations for camber allowances must take into account not only ordinary contraction, as commonly understood, but also the phenomena of post-solidification expansion peculiar to cast iron.

Mr. Longden, who was severely burnt some time ago, as a result of which he attended the conference on crutches, was complimented on his courage and tenacity in presenting his paper personally. Mr. Sutcliffe, commenting on the paper, emphasised the complexity of the problems associated with camber, and instanced, by means of sketches, a number of castings which cause trouble in the foundry. The phenomenon of pig-iron floating on the surface of fluid metal was discussed by the President, but no satisfactory explanation was given. Messrs. Hudson, Miles, Bird, and Fletcher were amongst the members who took part in the discussion, and all were apparently agreed that the subject matter as presented by the author was essentially practical and made a real and valuable attempt to present a means for the solution of one of the most persistent problems of the foundryman.

Distributors of Electric Resistance Alloys.

We are informed that the Telegraph Construction and Maintenance Co. Ltd., London, have entered into an arrangement with Wild-Barfield Furnaces, Ltd., Elecfurn Works, Holloway, London, N. 7, whereby this company will act as sole distributors of the following electric resistance alloys :—

" Pyromic," an 80-20 nickel-chromium for temperatures up to 1,150° C.

" Calomic," a nickel-chromium-iron for temperatures up to 1,000° C.

These alloys are melted in one of the latest types of electric induction furnaces. This method of manufacture, whilst not increasing the price, definitely eliminates impurities and makes the alloys very pure. The alloys are supplied in rod, wire, strip, and sheet, and owing to the absence of carbon, manganese, sulphur, etc., elements manufactured from them have a long life and freedom from hot spots, cracks, and surface disintegration.

We understand that " Pyromic " nickel-chromium has been under strenuous actual working tests in Wild-Barfield furnaces for some years past, while " Calomic " wire has been used by makers of domestic heating apparatus with the highest degree of success.

Repairs to Steel Furnaces

By Walter Lister

Prolonging the Life of Regenerators,

Many factors are involved in the successful management of the melting-shop in modern steelworks not the least of which are those that increase the working life of the plant. Some of these factors are discussed in this article.

THERE comes a time in the lives of all open-hearth furnaces when the renererating chambers show signs of becoming choked with slag and dust. It is noticed that, in order to keep a full body of gas in the furnace, it is necessary to increase the pressure in the culverts. But quite a lot of this extra gas blows out at the doors, because the draught is impeded at the other end by similar accumulations of slag and dust. With each succeeding charge it is increasingly difficult to get the bath up to tapping temperature. This condition is inevitable after a run of 10 or 12 months, and shows that the chambers require cleaning out and the chequer bricks renewing.

A premature demise is very often caused by careless furnacemen. It often happens that one end gives out much sooner than the other. This shows that the bad end has been burnt at some time, or some of the chequer bricks displaced by a "kick" of gas in reversing. Given normal conditions in every way, both ends of the furnace should wear equally. A melter who habitually overheats his furnace is usually responsible for unequal wear, and can easily reduce the life of his chambers by about 20%.

The slag pockets should be more than ample to contain all the slag likely to collect in twelve months' working, but I have known slag pockets full up and the slag running over into the chambers and among the chequer bricks after only a six months' run. The only slag that should get into the chambers is that unavoidably caused by fine particles of iron ore and lime being carried over by the draught and settling on the brickwork. This forms a thin slag which trickles down and gradually fills up the spaces between the bricks. A good plan to keep the slag pockets from filling up too quickly is to tap off the liquid slag after every two or three casts. This can be done when there is reason to believe that the slag has reached ground level. An iron bar can easily be driven through the wicket and the level of the slag ascertained. Of course, some of the slag will have solidified, but enough can always be run out to make it worth while. Besides, with less depth of slag in the pockets when the furnace eventually goes off for repairs, there is less work entailed in cutting it out.

ANALYSIS OF DUST AND SLAG FROM THE BOTTOM OF A GAS CHAMBER OF A BASIC FURNACE.

	Dust. %		Lumps. %
SiO_2	12·88	..	57·20
Fe_2O_3	41·57	..	22·85
Mn_2O_3	1·08	..	3·46
Al_2O_3	12·81	..	2·17
CaO	13·96	..	8·08
MgO	1·17	..	1·07
P_2O_5	0·43	..	0·16
SO_3	9·20	..	Traces
Cl	0·27	..	0·014
Loss by Calcn.	4·26	.	Nil

When the draught becomes so bad that there is more gas outside the furnace than in, and perhaps the increased pressure asked for is blowing the water seal out of the reversing valve, it is a sure sign that the chambers are nearing the end of their usefulness, and something has got to be done about it. But before shutting the furnace down for rebuilding, a few more weeks' work can always be got out of the furnace by putting on an auxiliary flue for the gas. As I have mentioned before, it is nearly always the case that one end of the furnace is working badly while the other end is still fairly good. This is where the value of an auxiliary flue comes in. As the accumulations of dust and slag at the bottom of the chamber stop the entrance of the gas and also the exit of the waste gases when the furnace is reversed, it is necessary to build another flue above ground and connect it with the chamber through the wicket as low down as possible in order to make as much use of the top layers of chequer bricks as possible. The idea is shown in the illustration, Fig. 1.

The main portion of the brickwork can be built up before the furnace taps, leaving only the connections to be made afterwards, thus saving considerable time. There is no need for the gas to be off for more than half an hour. As soon as the furnace is tapped and the bottom dried up, the gas should be shut off. Two labourers then knock in the man-hole of the gas culvert, while two others break through into the chamber, making a hole about 9 sq. ft. in area. All that remains to be done then is to roof the flue over with slab bricks or bearer bricks. As soon as the connections are made and everything rendered gas-tight, the gas can be turned in again and in another half-hour the furnace can be ready for charging once more. But this time it will be noticed that the gas, in its "goings out and comings in" will behave much better than before.

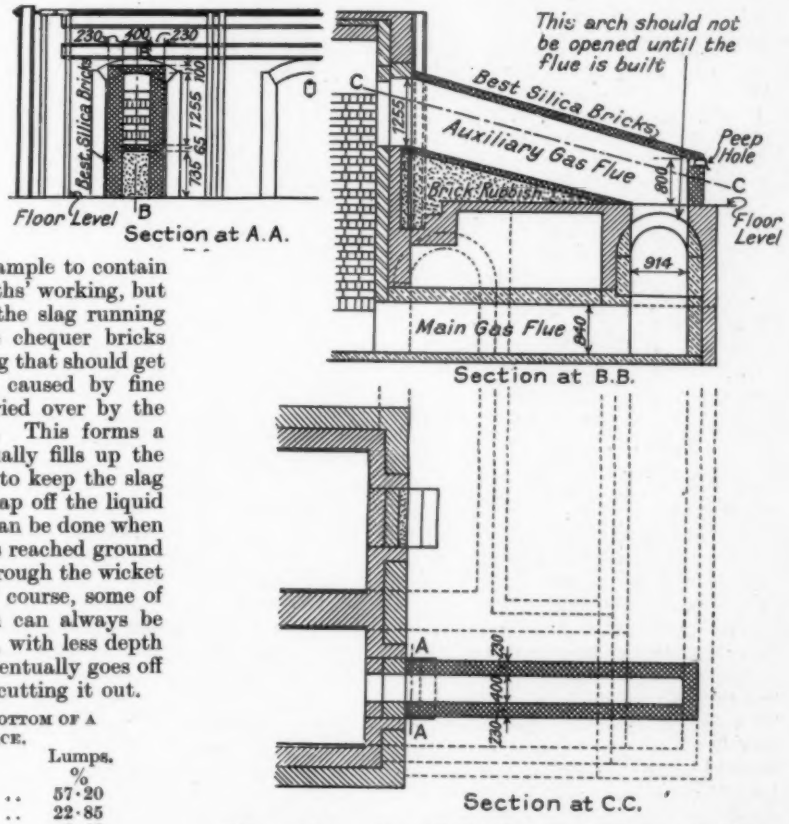


Fig. 1.—Siemens Open Hearth Furnace Auxiliary Gas Flue Arrangement.

It is not possible to work with this flue longer than a month, after which time the chamber refuses to regenerate, and if the other end is bad also by this time, it will be better

to shut the furnace down for complete renewals. I have tried to work with two auxiliary flues, one at each end but have never found it successful, it being really too much to ask of any furnace, even for a short time.

An alternative to building this flue outside the chamber is to cut a passage for the gas by taking out some of the chequer bricks. For preference, in order not to lose any production, this job should be done at the week-end. After the gas is taken off, the wicket should be cut completely out down to ground level. After that it will be necessary to allow the chamber to cool down for two or three hours. When cool enough to allow men to work, the outer bricks can be pulled out by means of hooks and rakes and a channel formed extending down to the bottom of the chamber. The bricks below the ground level can be broken off by means of long bars and lifted out with rakes or rabbles. A sketch of this method of prolonging the life of a gas chamber is shown in Fig. 2.

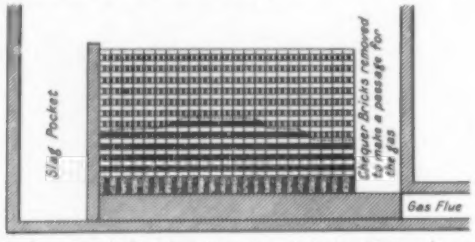


Fig. 2.—Sketch of a Gas Chamber choked with dust showing passage cut through.

This job should not take more than 12 hours. For instance, if the furnace taps at noon on Saturday, the passage should be cut and gas in the furnace by midnight Saturday. This will allow the furnace to be hot enough for charging about 2 p.m. Sunday.

This method may give the chamber a little longer life than the auxiliary flue, but the most that can be hoped for is about five weeks, as only a very small portion of the chequer work is made use of.

"Chimneying" the Chequers.

A longer life can be obtained by putting "chimneys" in the centre of the chequer work. But this, of course, cannot be done until the furnace is quite cold. The best time to do this is when the furnace has been shut down for a few days for repairs to side walls and ports. If there is reason to believe that the chambers will give trouble in two or three weeks' time, it is advisable to take the opportunity to put "chimneys" in.

The chambers should be cooled down as much as possible by opening the wickets at each end and lifting the chimney damper to its fullest extent. When cool enough, planking should be laid down on top of the chequers for the men to stand on. A hole or chimney, about 3 ft. square, is then cut through the centre of the chamber, by lifting out the chequer bricks right down to the floor of the chamber Any brick rubbish falling to the floor, as well as accumulations of flue dust, can be raked out by men entering the gas culvert from below. If both ends of the furnace are done in this manner at the same time, the chambers can be certain of at least eight to ten weeks' longer life.

It is hardly ever necessary to carry out on the air chambers, any of the operations mentioned, as the air never get so dirty as the gas. The gas chambers always collect a large amount of soot as well as dust from ore and lime. The chambers of acid furnaces always last much longer than those of basic furnaces, due to the absence of lime dust. For this reason the openings between the chequer bricks on acid furnaces can be made much smaller, thereby increasing the regenerative efficiency.

Chequer Renewal and General Repairs.

At last, of course, comes the time when no more patching up can be done and the furnace has to be shut down for general repairs, which means new chambers, blocks, linings, and roof—practically a rebuild. But it may not be necessary to put in a new hearth. If this is still good, the repairs necessary need not take longer than a fortnight. First of all, the furnace should be cooled down as quickly as possible by putting the valves on centres and lifting the chamney damper to its fullest extent. All doors should be taken off and the roof knocked in. The chamber wickets should also be taken out. If the furnace has been shut down on Saturday work can commence on Monday morning. The job of cutting out old brickwork on top and taking out the chequer bricks from the chambers, can go on simultaneously. The uptakes should be carefully examined. If the walls have been badly corroded, especially the dividing walls between air and gas, these should be cut down until a normal thickness of brickwork is reached. The old chequer bricks in the chambers will by now have probably been removed down to the ground level—that is, as far as the bottom of the wickets. It will be advisable now to lay plates or sheets on top in order to catch the rubbish coming down during the process of cutting down the uptakes. It is much easier to shovel this out through the wicket at ground level than to lift it out in buckets afterwards from the floor of the chamber, or carry it out through the culverts to the nearest manhole.

When all this has been cleared away, the plates or planking can be removed and the remainder of the chequer bricks taken out. At the end of the first week, the work on top—blocks, side walls, and roof—should have been completed. Down below, the chambers should have been cleared of all rubbish ready for commencing the laying of the new chequer work. The second week should see the chambers full of new bricks, slag pockets cleaned out, and all brick rubbish removed from the furnace on top.

Cleaning the slag pockets out is often a very difficult job, as the slag is very hard and dense. Ordinary sledge hammers and wedges have little effect. The only way in which the work can be done in reasonable time is by means of a pneumatic drill or pick. The drill is the best tool to use, as holes can be bored in the slag, wedges inserted, and by means of sledge hammers, large lumps broken off.

In order to prevent the slag adhering to the walls, and so facilitate its removal, the walls should be covered with about an inch of fireclay. This will allow the slag to be broken up without damage to the walls.

General Overhaul.

While the work of rebuilding is being done, men should also be cleaning out the culverts. During the course of a campaign, a deposit of soot and dust collects which in time would seriously reduce the capacity of the culvert if not removed. Advantage should be taken of the stoppage to clean all this out in both the air and gas supply.

Another item that often needs attention at these times is the condition of the walls of the gas supply from the reversing valve. Water may percolate down here and loosen joints, and in the course of 3,000 or so operations of the valve, bricks may become dislodged under the valve seating, probably allowing communication between two compartments.

In the case of a water-cooled valve like the Dyblie or Wellman, the trough should be cleaned out, as it will nearly always be found that a thick deposit of soot has set hard on the bottom, interfering with the proper adjustment of the valve.

Another item with regard to the valve trough is worthy of consideration. This is the depth of the water seal. I have had trouble on some furnaces by a constant blowing out of the seal under increased gas pressure at the back end of a campaign. In this case, the depth of water in the Dyblie valve was 230 mms. in the outer circle and 150 mms. in the diagonals. By increasing these to 280 mms. and 200 mms. respectively, I had no further trouble.

At these repair times also the state of the chimney damper should be inquired into. It is very necessary that the chimney connection should be efficiently closed at

(*Continued on page* 65.)

Determination of Iron Oxide in Liquid Steel

The results are given of an investigation to determine the true value of the oxygen content in liquid steel.

THE problem of inclusions in steel has become increasingly important, with the result that more and more attention has been paid to the source of these oxide inclusions. In killed steels the oxide inclusions are traceable to the reaction of deoxidisers, with the iron oxide dissolved in the steel during the refining period of the open-hearth heat. In a large class of steel known as "rimming steel," the action of the steel during solidification depends entirely on the gas evolved, and this evolution, in turn, is controlled by the amount of iron oxide in the liquid steel in the mould. It is therefore of great importance to be able to determine the amount of iron oxide dissolved, and to devise methods for the control of iron oxide in any class of steel. With the object of obtaining a true value of the oxygen content of liquid steel, an investigation has been carried out by C. H. Herty, jr., Hyman Freeman, and M. W. Lightner, the results of which are published in the U.S. Bureau of Mines' Report of Investigations, 3166. The data contained in this paper were obtained in a joint investigation by the United States Bureau of Mines, the Carnegie Institute of Technology, and the Metallurgical Advisory Board.

Deoxidation of Liquid Steel with Aluminium.

When undeoxidised or partly deoxidised steel solidifies, considerable quantities of gas are given off, of which CO is the major constituent. This CO is derived mainly from the reaction $C + FeO \rightleftharpoons CO + Fe$. Obviously a loss of CO on solidification would give a test-piece lower in oxygen than the liquid steel from which the test was poured. With this in mind the authors decided to attempt to precipitate the dissolved oxygen as Al_2O_3 by deoxidation of the liquid steel with aluminium. The analogy between this method and the ordinary sulphur determination is readily seen.

Description of Method.

Aluminium reacts with iron oxide in steel as follows :— $2Al + 3FeO \rightleftharpoons Al_2O_3 + 3Fe$.

This reaction is very rapid and results in the formation of refractory Al_2O_3, which is easily determinable by simple chemical analysis. The extent of deoxidation by aluminium has been investigated by Herty and Fitterer[1] who found the relationship $(\%\text{ of free Al})_2\ (\%\text{ of free FeO})_3 = 5{\cdot}7 \times 10^{-7}$ at steel-making temperatures. The amount of FeO in equilibrium with various amounts of aluminium in steel is shown in Table I.

TABLE I.

FeO—Al. Equilibrium in Steel (%).

Al.		FeO.		Equivalent Oxygen.
0·5	..	0·013	..	0·0029
1·0	..	0·008	..	0·0018
1·5	..	0·006	..	0·0013
2·0	..	0·005	..	0·0011

If 1·0% Al is added to the steel the amount of residual FeO will be very small, and may, or may not, be neglected according to the accuracy desired in making the determination.

The method proposed is deoxidation of the liquid steel with excess aluminium, determination of the Al_2O_3 formed, and conversion of this to its equivalent in FeO.

Sampling the Steel.

A test-spoon is well slagged and, as soon as the steel sample is withdrawn from the furnace, about 5 in. of ¼-in. aluminium wire is thrust into the steel. This amounts to about 1% of Al in a 2½-lb. test. It is necessary to remove completely the slag from the top of the metal in the spoon to eliminate certain variations in results, as will be explained later. It is best to avoid putting the aluminium wire into any slag on the spoon, as this causes a decrease in efficiency of the aluminium addition. As soon as the aluminium has been added, the steel is poured into a small mould, 1¾ in. square at the top, 1¼ in. square at the bottom, and 2½ in. deep (inside dimensions). It has been found advisable to use a sink head with this mould, to prevent piping in the small ingot. The test ingot is bored from the bottom with a ¾-in. drill. Studies of segregation of Al_2O_3 in these small tests show that there is irregular distribution in the piece ; therefore it is advisable to take as many drillings as possible to ensure getting a representative sample.

An unkilled test may be poured with each killed test and used as a blank for the FeO estimation. By analysing the unkilled test in the same manner as the killed test, the insoluble residue in the steel, together with the blank on the reagents, is obtained. In most work there is no need to run such a duplicate test on every sample. As a rule the blank is about 4% of the total aluminium found in the killed test.

Various methods of adding the alumina were carried out : (1) The aluminium was placed in the mould and the unkilled metal poured over it. This method gave erratic results, as the metal usually set so rapidly that only part of the aluminium dissolved ; (2) the aluminium rod was inserted into the stream of metal during pouring into the mould. In this test both cold and hot moulds were used. A comparison of these methods, with the method of killing in the spoon, is given in Table II.

TABLE II.

Methods of Adding Aluminium.

Method of addition—	Al_2O_3, %.
Killed in spoon	0·094
Aluminium in stream pouring into red-hot mould ...	0·090
Aluminium in stream pouring into cold mould	0·077

Segregation of Al_2O_3 in Test-Piece.

Two test ingots were split and drillings were taken at the top, middle, and bottom of the ingot, after the hot top had been sawn off. Three samples were taken at each plane at equal distances from one another, the centre sample being at the centre line of the ingot. Percentage values for Al_2O_3 were as shown in Table III.

TABLE III.

Proportions of Al_2O_3 in Various Sections of Two Test-Pieces.

	Ingot A.				Ingot B.		
Plane.	Outside.	% Centre.	Outside.	Plane.	Outside.	% Centre.	Outside.
Top	0·144	0·080	0·097	Top	0·138	0·223	0·140
Middle....	0·108	0·083	0·170	Middle...	0·164	0·134	0·192
Bottom ..	0·084	0·104	0·091	Bottom ..	0·184	0·144	0·158

On deep etching the segregation was very irregular, a condition always found in small ingots of aluminium-killed steel ; and in view of the irregular segregation the

piece was drilled deeply. To show that the drillings are representative of the sample the following Table IV. gives check results on the same drillings. The analyses were made several months apart.

TABLE IV.
CHECK RESULTS ON DRILLINGS.

Heat.	Sample.	Al_2O_3, %.	
		First Determination.	Second Determination.
46050	1—A	0·118	0·116
46048	1—A	0·103	0·099
40024	1—A	0·132	0·128
42102	1—A	0·099	0·102
42123	1—A	0·073	0·069
48100	1—A	0·100	0·102
43149	1—A	0·127	0·129
35092	1—A	0·106	0·106
45019	1—A	0·100	0·104

Effect of Excess Aluminium Added.

To determine whether complete deoxidation had occurred when the aluminium was added, and also to obtain the effect of excess aluminium on the oxygen content of the steel, three series of tests were taken from a basic open-hearth heat, the first series at 0·50% carbon, and the second and third series at 0·10% carbon. Six samples were taken in each period. The aluminium was added as ¼-in. pure aluminium wire, and the amount added was obtained by weighing the wire before and after use. Table V. gives the results of these tests.

After a certain amount of aluminium had been added the amount of Al_2O_3 obtained was practically constant, and an average of the determinations giving approximately constant results was used to designate complete deoxidation. These results show that up to 2·5 grms. of aluminium the amount of FeO recovered was directly proportional to the aluminium added to a 2½-lb. test. After this amount had been added there was no increase in FeO content of the metal shown, indicating (1) that essentially complete deoxidation had been obtained; and (2) that excess aluminium in the metal causes no increase in apparent oxygen content of the metal by deoxidising the slag in the spoon or by atmospheric oxidation of the contained aluminium. The results, it will be noted, were consistent, and indicate that the method is entirely satisfactory, provided an excess of aluminium is added.

TABLE V.
EFFECT OF EXCESS ALUMINIUM ADDITIONS.

Carbon, %.	Aluminium Added.		Al_2O_3 found, %.	Carbon, %.	Aluminium Added.		Al_2O_3 found, %.	Carbon, %.	Aluminium Added.		Al_2O_3 found, %.
	Grms.	%.			Grms.	%.			Grms.	%.	
0·50	None	None	0·0091	0·10	None	None	0·0100	0·10	None	(1)	0·0100
—	0·35	0·042	0·0139	—	0·95	0·119	0·055	—	0·50	—	0·0150
—	0·80	0·079	0·0166	—	1·05	0·218	0·060	—	0·60	—	0·0185
—	2·15	0·33	0·0315	—	2·80	0·536	0·121	—	2·25	—	0·0945
—	4·30	0·40	0·0365	—	4·20	0·583	0·122	—	5·15	—	0·094
—	8·45	0·79	0·0340	—	8·95	1·35	0·117	—	9·00	—	0·089
—	12·10	1·12	0·0370	—	13·5	1·35	0·118	—	11·70	—	0·090

(1) Tests on this series were not weighed.

When the metal has been deoxidised with silicon or manganese, almost all of the silica is reduced, and it would therefore be expected that almost all the MnO would also be reduced. Under these conditions the true FeO content of the steel is not determined; but the authors show that if the electrolytic method is used in conjunction with the aluminium method, it is possible to correct for SiO_2 and MnO.

The importance of removing all the slag from the surface of the steel in the test-spoon is emphasised, as a reduction of manganese and phosphorus may take place from the slag on the metal if it has not been completely removed.

Some Contracts.

Messrs. John I. Thornycroft & Co., Ltd., Basingstoke, have received an order from the Iraq Petroleum Co., Ltd., for twelve 6-ton six-wheel vehicles, with two-wheeled trailers, for transporting pipes in connection with the new pipe line to be established across Iraq and Palestine to the Mediterranean.

Messrs. Brown, Lenox and Co., (London), Ltd., Millwall, London, E. 14, have received an order from the Iraq Petroleum Co., Ltd., for 42 storage tanks in connection with developments which they have in hand.

The English Electric Co., Ltd., have received from the Galloway Water Power Co., Ltd., an order for five large water turbine alternator sets and three auxiliary sets, together with a quantity of switchgear and transformers, for the Longland and Glenlee power stations.

Messrs. Ruston-Bucyrus, Ltd., Excavator Works, Lincoln, have received an order for five electrically-operated excavators, mounted on caterpillars and equipped as shovels with buckets of 1 cub. yard capacity, from the Crown Agents for the Colonies, for use upon the new civil aerodrome at Singapore.

Morris Commercial Cars, Ltd., Birmingham, have received an order for 100 Morris Commercial 1-ton and 15-cwt. vans for postal service, from the General Post Office Stores Department; also an order for 44 2-ton and 30-cwt. Morris Commercial vehicles from the North-Eastern Railway Co.

The Glasgow Corporation has placed a contract for eight transformers with the Brush Electrical Engineering Co., Ltd., and another order for six transformers with Bruce, Peebles and Co.

Salop County Council has placed contracts for electrical and engineering work at the Berrington Hospital with G. H. Smallwood and Co., Ltd., and the Brightside Foundry and Engineering Co. Ltd.

Metropolitan-Vickers Electrical Co., Ltd., have been awarded a contract for six pairs of tramcar controllers and for fifteen pairs of light railway-type traction motors, from Sheffield Tramways Committee.

Messrs. Norris, Henty and Gardners, Ltd., Patricroft, have received an order for 91 Gardner four-cylinder heavy oil engines for replacing the petrol engines of a number of lorries that have seen lengthy service.

The Clyde Crane and Engineering Co., Ltd., Mossend, Lanarkshire, has been awarded a contract by the Galloway Water Power Co., Ltd., for one 60-ton overhead electric travelling crane, for the Longland power station, and one 50-ton overhead electric travelling crane for the Glenlee.

Drogheda Harbour Board have placed a contract for a crane for the coal quay with Joseph Boorg and Brothers, Ltd., Leeds.

Important orders, it is stated, have been recently placed in the United Kingdom by Arcos, Ltd., for electrical equipments on behalf of U.S.S.R. metallurgical works. These orders include one for the Mariupol and Taganrog rolling mills amounting to £70,000, one for electrical equipment for 15 cranes amounting to over £30,000, an order for 100 electric welding machines, £20,000, and one for pump and compressor motors, £30,000. The Chamber is informed that credits were arranged on all these orders for periods varying from 21 to 24 months from the date of delivery. Negotiations are pending with a number of British firms in respect to further orders of about £200,000 on similar credit conditions.

Messrs. Cambridge Instrument Co., Ltd., 45, Grosvenor Place, London, S.W. 1, have secured the order for the whole of the temperature-measuring instruments for the new Dunston Power Station, Newcastle-upon-Tyne. They have also received instructions to supply, through sub-contractors, a number of 13-in. illuminated-dial thermometers for the reheater steam pipes.

Recent Developments in Tools and Equipment

The Use of Steel in Mine Workings.

A Notable Design of Pit Prop.

EVERY year about £6,250,000 is spent by the British mining industries for wooden pit props, nearly all imported, although steel gives better results. In fact, mining is one of the most important new fields for the use of British steel generally, and comparable, for example, to steel railway sleepers, another example of the superiority of steel as compared with wood. In this connection of great interest is the "Bromford" tubular steel pit prop, manufactured by Bromford Tube Co., Ltd., of Birmingham, which essentially is a simple seamless tube made of special high tensile steel closed at the bottom in such a manner as to form a conical point of various degrees of sharpness.

It is well known that when the roof subsides or the floor lifts in a mine nothing can resist the enormous forces represented, so that the wooden props are soon smashed, and unless they are renewed at once a fall takes place. Many attempts have been made to design a collapsible or non-rigid form of steel pit prop which will reduce automatically in height when the weight comes on, whilst continuing to offer a resistance equal to or greater than a rigid wooden prop, so as to prevent a fall of roof.

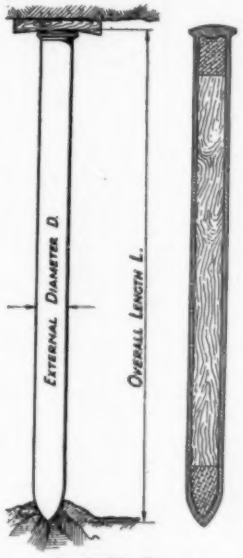
A satisfactory device of this character which is simple to set and withdraw, and free from such dangers as sudden collapse and flying out sideways is, however, very difficult to produce. The "Bromford" tubular prop may be described as a compromise between the rigid and non-rigid prop, and to a considerable degree possesses the advantages of both. Thus, a comparatively slender seamless steel tube of this character is stronger than the wooden prop, although the latter is much more bulky. Also, when weight comes on the steel tubular prop, instead of breaking or buckling, it is driven down, because of the pointed end, into the floor of the workings, whilst maintaining the maximum resistance of a powerful rigid prop, and thus preventing the fall of roof. Obviously, one of the great advantages is that a prop of this kind, whilst being movable vertically, is quite simple in design and entirely rigid without mechanical devices, moving parts, or complications of any kind liable to fail at the critical moment.

TABLE I.

Overall Length. Ft. In.	External Diameter and Thickness. In.	Weight Empty. Lb.	Collapsing Load Empty. Tons.
3 6	3½ × ¼	33·596	80·75
4 0	4 × ¼	44·165	91·14
4 9	3½ × ¼	44·434	71·00
5 0	4 × ¼	54·165	84·10
5 6	3½ × ¼	50·936	66·00
5 9	4 × ¼	61·615	78·60
6 0	3½ × ¼	55·372	62·50
6 6	4 × ¼	69·165	73·30
6 6	4½ × ¼	73·640	91·00
7 0	4½ × ¼	79·310	87·25
7 6	4½ × ¼	84·970	83·70

These tubular steel props are supplied of any length, with outside diameter and thickness in proportion, according to the conditions they are required to meet and are also made empty or filled with sand which is highly compressed by the process of manufacture. This prevents buckles, or dents being formed should the props be bent in use, and is also a great help in straightening. If, however, the conditions are such that no likelihood exists of bending, the empty prop is preferable owing to its being lighter and so easier to handle.

A few typical figures are given in Table I. for some different sizes of empty props, which are generally in standard lengths from 3 ft. 6 in. to 6 ft. 6 in., and 3½ in. to 4 in. in diameter :—



Steel Pit Props.

In use down the pit the prop is set in the ordinary way, with wooden top-piece or split bar, and when driven down into the floor it fractures the strata around equally in all directions from the point of contact, so that withdrawal is generally quite easy. When the conditions are unusual in this respect and prop-withdrawing difficult, the steel props are supplied with a lug welded on about 6 in. from the top, suitable for the hook of a Sylvester chain. The chain can be passed round two or three times and hooked into the lug, so that a powerful twisting effort can be exerted without the chain becoming detached when the prop is withdrawn.

Application of high-grade steel tubes in place of timber is rapidly gaining ground in mining, and as compared with steel the general disadvantages of wood include inferior strength, liability to deterioration, danger of fire, and growing world scarcity with rising prices.

Repairs to Steel Furnaces

(*Continued from page* 62).

week-ends, especially when the furnace has a lying-in charge. But I have often noticed cast-iron slots lying corroded and broken on the floor, bricks missing out of the damper itself, and various other monuments to neglect and bad management, which, combined together, make the damper of so little use that it really matters very little whether it is open or shut.

By the end of the second week, all these jobs should have been done. The banks of the furnace hearth should have been re-rammed where required, and a new tap-hole made. By noon Saturday a wood fire should be burning on the hearth, and at about midnight gas should be introduced.

A precaution that should always be taken when commencing with new chambers is to light a fire in a grate at the bottom of each chamber, on the outside of the wicket farthest away from the stack. A couple of bricks should be taken out of the wicket, so that the flames and heat of the fire are drawn through the chambers and up the stack. These fires should be lighted as soon as all repairs are complete. A further precaution, in order to ensure a good draught when gassing, is to light a fire at the bottom of the chimney stack in the same way as those at the bottom of the chambers.

In these days of low profits (and sometimes no profits at all) all the points I have dealt with are more or less vital factors in the successful management of any melting shop. In steelmaking more than in any other business, it is necessary to take care of the pence in order that the pounds may take care of themselves.

Annual Meeting of the American Society for Testing Materials

THE thirty-fifth annual meeting of the A.S.T.M., to be held at Atlantic City on June 20–24, has been arranged on a very comprehensive scale. According to the provisional programme, fourteen sessions have been planned, five pairs of which are arranged to run simultaneously. In order to stimulate interest and to point out the importance of statistical methods in the acquisition of good data, a round table discussion has been arranged for the afternoon and evening on the first day of the meeting. The statistical nature of the Society's data will be presented in an informal paper. Methods of dealing with discordant observations will be discussed; a unique and more or less physical method of dealing with them will be presented. One paper will summarise the latest information in regard to the contribution which mathematics and statistics make to this problem, while others will outline various methods of value in eliminating constant sources of error in research work, and the present position of statistical theory with suggestions as to the developments necessary to make it more useful.

An important problem of special interest to all who use standards is the establishment of methods of inspection to see that quality standards are met, and three papers arranged for the evening discussion will point out how the work reported in the afternoon session has been used in the development of improved methods of setting quality and inspection methods.

In addition to the informal papers which will serve as a basis of introducing discussion at the round table conference, three formal papers giving concrete applications of statistical theory will be presented in sessions of the annual meeting with the general subjects with which they are involved. In the session covering steel and magnetics, for instance, a paper on "Specifications for the Gauge of Sheet Metals in Terms of Quality Control" is arranged. This discusses inspection methods adapted to a specification for the gauge of sheet metals which permits the estimation of the probability that any portion of a sheet lies within given limits with respect to the nominal gauge. In the session which involves corrosion and fatigue of metals, a paper is to be presented on "Controlled Data from an Immersion Test," which will explain the relationship between time and loss of weight of the immersed specimen.

A symposium on steel castings has been arranged to occupy two sessions. Ten papers are to be presented covering many of the important technical phases of steel castings, such as methods of moulding, casting, use of alloys, and heat-treatment. A contribution on welding is included which considers this subject from the viewpoint of steel foundrymen. Three papers are involved in the general topic of the development of alloy steel castings: thus the symposium will be of interest to producers and users of both carbon and alloy steel castings.

Reports of committees and papers will present varying aspects of problems associated with steel. The reports will include tentative revision of standard definitions of terms relating to heat-treatment operations; new tentative specifications for ferro-tungsten, low-carbon ferro-molybdenum, and for molybdenum salts and compounds; also methods for the chemical analysis of ferro-tungsten and ferro-molybdenum; on iron-chromium, iron-chromium-nickel and related alloys; new tentative specifications for structural medium steel, structural rivet steel and electric-fusion-welded steel pipe, and a suggested extensive revision of standard method of test for magnetic properties of iron and steel for publication as tentative. Novel fatigue tests applied to wire and wire rope will be described in one of the papers, while others will discuss the deoxidising efficiency of zirconium alloys compared with other deoxiders, and present results on an investigation on the magnetic properties of hardened steels.

At another session committee reports will be presented on wrought iron, malleable castings, cast iron, and on the effect of temperature on the properties of metals. The requirements of an extensometer for tension tests at high temperatures covering the advantages and disadvantages of existing apparatus will be discussed in a paper. Another paper to be presented discusses certain temperature effects in connection with the use of elastic-number calibration devices, taking into account the effect of thermal factors upon ordinary extensometer measurements, and upon measurements made to determine the amount of creep.

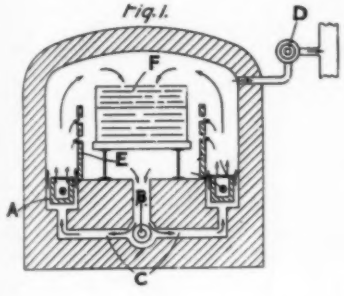
The corrosion and fatigue of metals will form the basis for discussion at another session at which, in addition to reports, papers will be given on embrittlement of hot-galvanised structural steel, the effect of zinc coatings on the endurance properties of steel, and factors affecting the Preece test for zinc coatings. Two papers will consider fatigue problems: one describes the two types of straight keyways in common use, the sled-runner and profiled types, and presents results of fatigue tests made on specimens. These tests show that the sled-runner keyway is 30 per cent. stronger in fatigue than the profiled keyway for chromium-nickel steel. Tests on medium-carbon steel are also included. Stress concentration factors are given and some theoretical aspects are discussed. The other presents results of tests made on flexure specimens of structural steel and of rail steel, T-shaped, and so tested that the stem of the T is subjected to repetitions of compressive stress, while the maximum tensile stress in the flange of the T is distinctly lower than the compressive stress in the extreme fibre of the stem of the T. The specimens are tested in a repeated-axial-stress machine fitted with an attachment for flexure tests under one-directional bending moment, the bending moment varying during a cycle from a very small value to a maximum, with no reversal of bending moment.

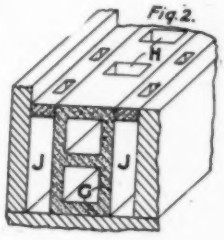
Non-ferrous metals and metallography will be considered at two sessions. Reports of committees will be presented on the corrosion of non-ferrous metals and alloys; copper wire; screen wire cloth; copper and copper alloys, cast and wrought; die-cast metals and alloys; light metals and alloys, cast and wrought; electrical heating, electrical-resistance and electric-furnace alloys; and on metallography. Data on the extent to which impact strength is dependent upon the cold working of Monel metal will be presented in a paper, while results of long-time creep tests conducted on non-ferrous alloys of the copper-zinc, copper-zinc-tin, and nickel-copper series, at temperatures both above and below their lowest recrystallisation temperature, will also be presented. Factors affecting the physical properties of cast red brass of the 85–5–5–5 type will be discussed; results of tests made on a series of lead- and tin-base bearing alloys, and an alloy of cadmium-zinc for the determination of their mechanical properties will be presented. These latter tests include the determination of wear resistance, resistance to pounding, Brinell hardness, stress-strain relations in compression, and impact resistance by the Izod notched-bar method. The wear specimens tested on the Amsler wear-testing machine at room temperatures only, are wetted by a continuous flow of kerosene for the purpose of preventing oxidation and overheating, and for the maintenance of constant temperature. Methods of preparing lead and lead alloy cable sheath for microscopic examination is another noteworthy contribution.

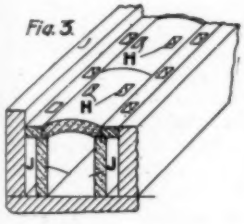
Some Recent Inventions.

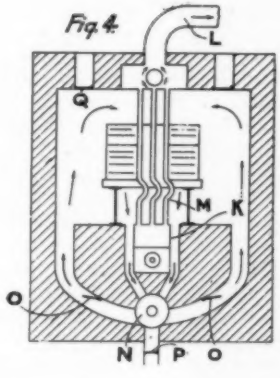
Heating Ovens Efficiently.

RAPID heating under uniform temperature conditions may be accomplished by heating large quantities of air which are passed at a rapid rate through a heating chamber. The rapidity of passage past the material under treatment will tend to secure uniformity of temperature if the air is uniformly heated, and is supplied in sufficient quantity. As ordinarily carried out, a process of this kind involves the burning of a large amount of fuel. The object of a recent improvement in heating chambers is to provide a more efficient heating arrangement minimising fuel consumption and providing a uniform heating temperature. This improvement comprises the recurring circulation of the gases in contact with heating means and through a chamber containing the materials to be treated.









In the oven shown in Fig. 1 combustion products are generated in combustion chamber A made of good heat-conducting and radiating material, such as silicon carbide, and are continuously diluted by cooled gases withdrawn from the oven by a fan B and returned around the combustion chambers through flues C. Surplus gases are drawn from the system by a fan D. Perforated baffles E, made of good heat-conducting material such as sheet metal, direct the inflowing heating gases to the top of the charge F.

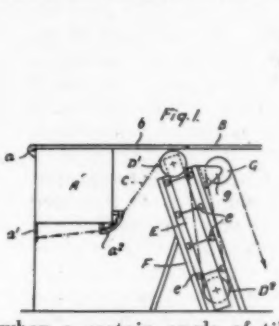
A double-pass combustion chamber G, shown in Fig. 2, consists of two superposed communicating compartments, in the lower of which combustion is effected, while the upper one has apertures H leading to the oven. The chamber is flanked by cool gas return flues J roofed by perforated plates. A similar construction with a single-pass radiating combustion chamber is shown in Fig. 3.

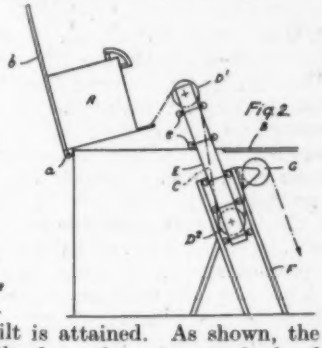
When the charge is to be heated without contact with combustion products the chamber K communicates with an exhaust flue L, Fig. 4, by conduits M extending through the oven. The atmosphere of the oven is circulated through the charge and over the combustion chamber by a fan N, and a change of atmosphere is effected at intervals by closing dampers O and opening dampers P, Q.

360,885. THE CARBORUNDUM CO., LTD., of Trafford Park, Manchester, patentees; Messrs. BOULT, WADE AND TENNANT, 111, 112, Hatton Garden, London, E.C. 1, agents.

Tilting Furnaces.

THE accompanying illustrations, Figs. 1 and 2, show an arrangement for tilting a furnace or other apparatus through an angle greater than 90°. The tilting of the furnace is effected by a pulley system, which in its inoperative position is entirely below the platform under which the furnace is located, but is automatically lifted





when a certain angle of tilt is attained. As shown, the furnace A is arranged to tilt about the axis *a* at the level of the platform B; a door *b*, normally at the same level as the platform, moves with the furnace as the latter is moved about its pivot *a*. The rope C passes round two pulleys freely, mounted at the ends of a carriage E, which is slidable in a fixed frame F. The free end of the rope is led to a winch, and the friction of the sliding carriage is reduced by rollers *e*, which are secured to the carriage.

As the rope is wound up by the winch, the furnace is gradually tilted about its pivot, the sliding carriage remaining in its original position as shown in Fig. 1; when, however, the furnace has been tilted through about 90° and further movement is necessary, the sliding carriage automatically slides upwards and takes up the position shown in Fig. 2, in which any further upward movement is arrested by a suitable stop.

360,247. G. E. TAYLOR, L. E. THOMPSON, and ENGLISH ELECTRIC FURNACE CO., 17, Victoria Street, London, S.W. 1, patentees.

Improvements in Fine Drawing Dies.

IT is customary in the manufacture of fine drawing dies, such as those made of sintered material like "Widia," to press the hard metal inset into a holder of brass or unalloyed steel while hot. These metals, however, have a much greater coefficient of expansion than hard metal, and owing to the unequal shrinking of the hard metal and the material of the holder, stresses arise which often lead to the occurrence of cracks in the hard metal inset, either immediately or during use.

A recent improvement aims at producing hard metal fine drawing dies, in which the hard metal inset is free from stress. This object is attained by inserting the hard material in a holder of which at least that part in contact with hard insert is made from a material which has approximately the same coefficient of expansion as the hard metal. In this way the holder and insert shrink uniformly, and therefore no stresses arise. With inserts made from the known hard materials, which consist mainly of tungsten carbide and have a coefficient of expansion of about 5×10^{-6} per ° C., nickel steels containing from 39 to 45% nickel have been found to be suitable.

Instead of manufacturing the whole holder of a material with a coefficient of expansion corresponding to that of the hard metal insert used, the hard metal insert may be surrounded by a piece of foil of a material with a corresponding coefficient of expansion, and then, for example, soldered into a holder of chromium steel or chromium nickel steel of high resistance to corrosion, the coefficient of expansion of which is diff rent from that of the hard metal.

361,831. TOOL METAL MANUFACTURING CO., LTD., of 11, Victoria Street, London, S.W. 1, patentee; GILL, JENNINGS AND EVERY-CLAYTON, 51-52, Chancery Lane, London, W.C. 2, agents. Accepted November 26, 1931.

British Non-Ferrous Metals Research Association.

THE annual meeting of the Association was held at the Savoy Hotel, London, on June 7, when addresses were given by Sir Auckland Geddes, Sir Frank Smith, F.R.S., and Mr. Thomas Bolton. The report of the year's work, issued on this occasion, gives details of the extensive programme of research, the progress of the development section, which aims at stimulating industrial application of the results of research, and the information services provided for members.

Both the report and the speeches at the annual meeting clearly indicate the value of the Association's work to its members and to the progress of the metal industries, for tangible results of direct commercial applications are now being secured to a rapidly growing extent. It is encouraging to note that, despite the intense industrial depression, this Association has received in subscriptions from its members a larger sum than in any previous year. The total income, with Government grant, is over £25,000, and a very extensive programme of work is being carried out.

A section of the report deals with the future outlook, and claims that even greater success would promptly accrue from the more intensive co-operation of existing members and from a moderate and steady increase in the funds available to the Association. Amongst new materials which have been made available to industry by the Association's researches, the elastic "Stayput" copper for locomotive fireboxes, the new ternary alloys for cable sheathing and water pipes, and the aluminium-brass condenser tubes are of outstanding importance.

It is interesting to note that during the year about 2,400 tons of the new ternary alloys were used in the United Kingdom for cable sheathing. Attempts are being made to collect more definite comparative data as to the behaviour of different cable sheathing materials in service. Some confusion of thought appears to have existed on the part of users not directly connected with the Association as to the relative merits of the different ternary alloys for particular applications. In order to simplify the position a booklet has been prepared, surveying the research on the properties of lead from the point of view of cable sheathing, and setting forth clearly the advantages of the ternary alloys for this purpose.

Great progress, however, has been made during the year. The Board of Trade has granted a standardisation trade mark, and many lead manufacturers have taken out licences to manufacture these ternary alloys. Further, it is of interest to note that the British Waterworks Association, after a thorough review by a special committee, has recommended acceptance of the B.N.F. ternary alloy pipe as a substitute for lead pipe, with a 30% reduction of weight. This recommendation is for the moment restricted to the use of the alloy in buildings. The Association has, however, confidence that the tests in hand will prove that the ternary alloys are not more subject to soil corrosion than lead itself, and that their improved mechanical properties offer a prospect of valuable service underground, particularly in urban districts where vibration troubles are so frequent.

The practical nature of the Association's work is further indicated by the researches it has in hand on such subjects as the frost-bursting of water pipes, the effect on health of the use of aluminium cooking vessels, bearing metals, the tarnishing of metals used for shop fronts, etc., and last, but not least, the searching inquiries which it is undertaking for its members on the improvements of the efficiency of industrial production.

Among the latter is one which refers to the difficulty experienced in producing common brass sheet free from blisters, and a considerable amount of experimental work has been carried out in an endeavour to elucidate this problem. Ingots have been cast by a number of methods designed to give variations in the type of macrostructure and distribution of porosity. These have been rolled by different commercial firms, and the quality of the sheets correlated with the methods of casting and the quality of the original ingots. This preliminary work has indicated that the problem will require more comprehensive experimental work for its solution than had been anticipated, and further inquiries among members have shown the defect to be one of interest to a large section of the trade.

The research on alloys for high-temperature service has advanced considerably during the past year according to the report. Continuing with the original decision to take the well-known 80/20 cupro-nickel alloy as a base, and the additions of small quantities of aluminium, silicon, titanium, molybdenum, chromium, etc., with regard to their effect on the mechanical properties and resistance to oxidation, a number of ternary and also a few quaternary alloys have been made and their properties determined. In certain cases the proportion of copper to nickel in the base alloy has been varied.

The work on these alloys has also been considerably assisted by the installation of the special slow-tensile-testing machine for elevated temperatures, designed and constructed for the Association by the Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester.

Some progress has been made in preparation for the commencement of investigations on the soundness of castings and on other problems connected with the casting properties of metals. So far the Association has, apart from die casting and aluminium castings, had little contact with the foundry industry. It is thought that much of the Association's past work on die castings, gas inclusions, and porosity, can afford service to other sections of the industry, particularly if the Association can equip itself to apply and extend these investigations to a study of typical non-ferrous foundry products.

The growth of the Association in recent years undoubtedly has been remarkable, but from the report it is obvious that great difficulties are still met with in financing the research and other work which has been planned. Considering the large extent of the field of industry which is covered by this Association the present membership of 200 is much too limited. The tangible results which can be shown have been of great benefit to the engineering industries, but those who ultimately benefit as users of metals apparently provide very little financial support to the Association, the subscriptions coming mostly from the metal manufacturers themselves.

All sections of the industry should be prepared to follow the lead of the pioneers by joining the Association. This applies particularly to the users of non-ferrous materials, who, despite the fact that they have already received great financial benefit from improved materials originating in the Association's researches, still hold aloof.

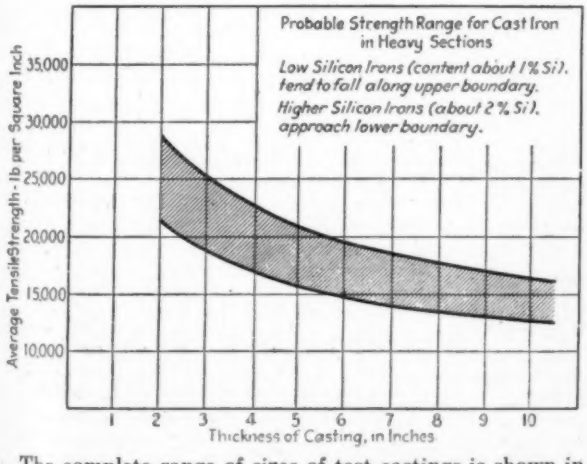
There can be no doubt about the successful character of the work accomplished and the valuable work performed by the Association in facilitating the progress of non-ferrous metals. This is not only a national work of great importance, but it is of vital importance to all manufacturers and users of non-ferrous metals, and this report deserves the careful attention of all concerned. A copy can be obtained on application to the Association's Headquarters, Regnart Buildings, Euston Street, London, N.W.1.

Effect of Sectional Thickness on Strength of Grey Iron

As a result of an investigation the conclusion is formed that the strength of castings of different thicknesses follows a fairly definite law.

IT is generally recognised that the thickness of metal in a casting affects the properties for a given composition. The slow cooling of heavy sections results in a softer and weaker iron than is obtained in thin sections, which, by comparison, cool quickly. It is not generally recognised, however, to what extent the strength of a casting is affected by its size and section. In order to obtain specific information as to the strength which might be reasonably expected from castings of various sizes and compositions an investigation has been carried out by Messrs. F. P. Gilligan and James J. Curran.*

Castings of various sizes and compositions were made and tested. These were obtained from six heats melted in the cupola, according to regular practice. Test-bars and blocks varying in size from 1 in. to 10½ in. in thickness and weighing up to 4,000 lb. were cast on end from each heat, and the castings were cut to obtain specimens for tensile tests. The tests, in the case of the 1-in. and 2-in. bars, were taken as nearly as possible half-way between the centre and the surface, and in the larger bars from near the centre and at the surface, and the results averaged. In the case of the 10½ in. by 30 in. by 48 in. castings six specimens were taken from each near the surface and centre, at top, middle, and bottom.


Probable Strength Range for Cast Iron in Heavy Sections
Low Silicon Irons (content about 1% Si). tend to fall along upper boundary.
Higher Silicon Irons (about 2% Si). approach lower boundary.
Average Tensile Strength - lb per Square Inch
35,000
30,000
25,000
20,000
15,000
10,000
1 2 3 4 5 6 7 8 9 10
Thickness of Casting, in Inches

The complete range of sizes of test castings is shown in Table I., and the compositions of the six heats in Table II. The average tensile results obtained are tabulated in Table III. Heat B was intended to duplicate and supplement Heat A, and they are very close in composition, although the natures of the charges were quite different.

While the number of distinct castings made is not as large as might be desired for scientific accuracy, the authors are of the opinion that the results of the investigation indicate that the strength of castings of different thicknesses follows a fairly definite law, and that the effect of composition is greatly minimised as the section increases. The close grouping of all the results on the castings of greatest thickness, 10½ in., in which the greatest number of tensile tests were averaged, indicates that in large sections, of this order at least, composition plays a decidedly minor part.

With the data available it is possible to establish a probable strength range for castings of all compositions in heavy sections, and such a range, as prepared by the authors, is shown in previous column for sections of 2 in. to 10½ in. thick.

TABLE I.

RANGE OF SIZES OF CASTINGS.

Section, In.	Length, In.	Weight, Lb., Approximate.
1 × 1	15	4
2 × 2	24	24
4 × 4	24	96
6 × 6	36	324
8 × 8	36	576
10½ × 10½	36	1,000
10½ × 30	48	3,800

TABLE II.

COMPOSITIONS OF HEATS USED.

	Total Carbon.	Manganese.	Silicon.	Phophorus.	Sulphur.
A	3·40	0·51	1·94	0·570	0·070
B	3·16	0·45	1·95	0·646	0·108
C	3·18	0·54	1·39	0·240	0·064
D	3·36	0·44	1·40	0·298	0·099
E	3·36	0·43	2·15	0·689	0·101
F	3·87	0·34	1·07	0·095	0·057

TABLE III.

TENSILE STRENGTHS OF CASTINGS.

Heat	A	B	C	D	E	F
Silicon content	1·94	1·95	1·39	1·40	2·15	1·07
Size.	Average Tensile Strength, Lb. per Sq. In.					
1 in. square × 15 in.	33,550	33,700	33,350	32,800	29,200	21,880
2 in. square × 24 in.	20,950	—	26,550	—	—	—
4 in. square × 24 in.	16,600	—	20,400	—	—	—
6 in. square × 36 in.	16,150	—	20,200	—	—	—
8 in. square × 36 in.	9,725	14,275	15,000	21,475	—	—
10½ in. square × 36 in.	—	13,825	—	15,625	—	—
10½ in. × 30 in. × 48 in.	—	—	—	—	14,700	15.700

This range approximates closely to the average strength of grey iron in large sections, regardless of composition. For design purposes the values included in the range are a safer guide than the usual guesses based on test-bar strengths. The curves, the authors point out, refer only to cupola irons of the ordinary types, and not to alloy irons or the newer high-test irons. Data on these are scarce, but their experience indicates that the benefits derived from alloy additions, all-steel charges, and superheat may be retained to a greater extent in such heavy sections.

Closing Shipyards.

Sir James Lithgow, Bart., of Glasgow, chairman of National Shipbuilders' Security, Ltd., reviewing the financial position of the company at its third annual meeting in Edinburgh, said that during the year substantial progress had been made in the industry's co-operative efforts to deal with the problem of redundant capacity in an ordered and equitable manner.

During the year under review, eleven shipyards had been purchased for scrapping, or under restrictive covenants against shipbuilding.

Since the close of the financial year on March 31 two additional establishments—the shipyards of Messrs. Bow, McLachlan and Co., Ltd., Paisley, and of Messrs. Earl's Shipbuilding and Engineering Co., Ltd., Hull—had been purchased subject to the completion of legal details.

The company were also in negotiation for the purchase of other yards, both in Scotland and England.

* "Effect of Section on Tensile Strength of Grey Iron." *The Iron Age*, Vol. 1[illegible], No. 20, pp. 1106-1107, 1125.

Business Notes and News

A New Steel Flooring.

The development of new a steel flooring after long scientific investigation has been announced by Mellon Institute of Industrial Research, Pittsburgh, Pa. This flooring consists of slabs, 24 in. wide and up to 12 ft. 5 in. in length at present, that are fabricated by preforming two steel sheets and subsequently welding them together in the plane above the neutral axis. A cross-section taken through the width of a completed unit shows four keystone-shaped cells, all connected together near the neutral axis. These four ducts, which constitute each unit, are spaced at 6-in. intervals and connect directly, when installed, with the corresponding ducts of the adjacent section of floor slab. This arrangement is described as enabling the utilisation of the new floor not only as an efficient load-carrying member, but also as a multiple floor-duct system for handling all types of electrical lines. Such a grouping of parallel cells with 6-in. spacing is claimed to permit, at any time, the installation of electrical outlets within a radius of 3 in. from the exact location required, thus providing permanent electrical flexibility and precluding electrical obsolescence.

It is claimed that the keystone slab can be installed with ease and rapidity; that it can be bolted, clipped, or welded into place across the structural members, affording a working floor for the various trades. This type of floor is fireproof; it is adaptable to appropriate finishes and to suspended ceilings and service piping, and has a low weight per square foot.

"Creep" Measurement Method Developed.

Results of research on the measurement of creep in metals under stress, which have been carried out at the University of Michigan, are expected to be of considerable importance in many industries in which metal parts are designed for use at high temperatures. At high temperatures metal under stress changes its shape with extreme slowness, and this almost imperceptible change in size or shape is claimed to have been measured with special instruments which give continuous readings accurate to one-millionth of an inch. With the trend of industry towards the use of high temperature and high pressure in order to increase efficiency from power plant, boilers, oil-refining apparatus, chemical plant, etc., accurate means of determining creep changes is recognised as of fundamental importance in the design of reliable and safe machinery.

As a result of research several methods of measuring creep were developed by Professor Stephen Timoshenko and Dr. F. L. Everett in the University Engineering Research Laboratories. The most accurate method devised consists of a new application of twisting force, instead of the pulling force commonly used, and employs a system of mirrors attached to the specimen which, together with telescope and graduated scales, permit detection of extremely minute creep movements. Further investigations are proceeding in this direction.

Electric Furnace Co. Report.

Despite the difficult times the Electric Furnace Co. Ltd. has maintained business at a satisfactory level. According to the report to be presented at the fourth annual general meeting to be held on June 22, the net profit is larger than that of last year. Important technical progress has been made, and considerable time and money have been spent on research and development, which should prove profitable with improvement in trade. Electric furnace installations having a total power of over 21,000 kw. were on order at the end of the year, some of which are of outstanding technical interest. High-frequency furnaces installed in the Sheffield district have attracted much favourable comment; the furnaces at the Dagenham Works of Ford Motor Co. are approaching completion, and notable installations are being made in two well-known Swedish steelworks, the results of which are being watched with interest. Among plant of special technical interest ordered during the year may be mentioned twenty-ton arc furnaces of 5,000 and 6,000 kw., and five-ton high-frequency installations of 1,250 kw. input. The former units are as powerful as any similar furnaces built in England, while the latter is the largest unit of this type yet constructed.

Fuel Research in Relation to Transport

At the Congress of the Institute of Transport held recently at Buxton, Professor R. V. Wheeler, in discussing fuel research in relation to transport, pointed out that, assessed on the basis of the value of the goods carried, the most important transport service is the marine merchant service. The fuel used in ocean-going and coastwise vessels before the war was almost invariably coal, but, as with warships and liners, many large cargo-carrying vessels now use oil, either for steam raising or in internal combustion engines. In ocean-going ships space is valuable, and about two-thirds more space is required for coal than for oil to render the same service as a boiler fuel. Moreover, oil can often be carried in double-bottomed compartments which would otherwise be filled with ballast. Ocean-going vessels can usually obtain renewed supplies of oil where it is cheap, whereas coaling may be expensive. On the other hand, in European coastwise trade, coal can generally be bought more cheaply, and the shorter voyages do not cause space in the vessel to be a major consideration. For such traffic then, coal will probably continue to be the principal fuel. The utilisation of coal is, however, being improved and steady progress has been made in the application of pulverised fuel to the marine boiler.

On the railways, although the modern British locomotive is most reliable and can deal effectively with the necessary loads, its efficiency is low compared with that of stationary power plant. This low efficiency is due in part to the restricted dimensions of the locomotive boiler and in part to the fact that accessories which would increase efficiency might reduce reliability, the primary requirement. Many attempts have been made to adapt pulverised fuel to railway locomotives to obtain increased efficiency, but experiments in this country do not appear to have made much progress. In America and in Germany, however, locomotives using pulverised fuel have passed the experimental stage.

Professor Wheeler referred to the achievement of Imperial Chemical Industries, Ltd., in producing petrol and oils from bituminous coal by hydrogenation, and suggested that the extensive operation of such a scheme would have far-reaching effects.

Important Steel Interests Co-operate.

An important agreement has been entered into by two companies which together control more than one-fifth of the iron and steel output of this country. The arrangement has been made between United Steel Companies, Ltd., one of the most important groups in the steel trade, and Stewarts and Lloyds, Ltd., the iron and steel tube makers. It provides for co-operation in the policy of extensions in steel production and avoidance of uneconomic duplication of plant. There will also be co-operation in sales policy, in research, and in technical development and production methods. The directors of the two companies have been influenced by the new situation brought about by the imposition of tariffs, which they state encourages and requires undertakings in the steel and complementary trades to plan for the future and to enter into arrangements having for their object the economic development of the industry and the prevention of overlapping and duplication of plant for those markets where the productive capacity is already fully sufficient for the demand. In their opinion the economic development of the industry is in the national interest and they believe that the agreement by their undertakings to co-operate in the general policy would be helpful in advancing this object.

This arrangement may well prove to be an initial step in a national selling policy for the British iron and steel industry.

New Open-Hearth Furnaces and Automatic Reversal Equipment.

It is of interest to note that Messrs. G. P. Wincott, Ltd., of Sheffield, recently received a contract for the supply and erection of three open-hearth furnaces for the English Steel Corporation, Ltd., Sheffield. These furnaces will be equipped with Leeds and Northrup automatic reversing equipment which will be supplied by The Integra Co. Ltd., of Birmingham. This equipment for the automatic reversal of the air and gas valves is based on a temperature-difference control and eliminates the mistake of reversing the furnace on a time cycle.

THE EFFECT OF HYDROGEN IN RIMMED STEEL.

VERY low-silicon steels—in which no silicon has been added in the final additions, and which are only partially deoxidised,—known as rimmed steels, produced in the open-hearth furnace and used for plates, shapes, pipes, sheets, wire, nails, etc., are often adversely affected by the presence of hydrogen, says Henry D. Hibbard.* He states that hydrogen exists in iron and steel in at least three different forms—viz. : (1) That which is absorbed by iron deposited from solution by an electric current—*i.e.*, in electrolytic iron. This hydrogen may escape to some extent at room temperatures, and does so copiously, so that it may be burned in a flame, when the iron is heated moderately to about 300° C. Such hydrogen is not chemically combined with the iron or even in solution, as shown by its easy expulsion. (2) That taken up in steel when the metal is pickled in acid, as when cleaning its surface of scale. This hydrogen tends to make the steel brittle when cold, but it may be expelled, and the brittleness overcome by heating to 600° or 700° C. (3) That taken up by the melted iron, which acts as if in solution, and is certainly in a different state from (1) and (2), because heat will not expel it from the molten metal, but on the contrary will give the iron power to hold it. The hotter the iron—within limits perhaps—the more strongly it holds its hydrogen. Cooling tends to set it free, but this may occur too late for its harm to be avoided.

Manganese should not be too high in the crude iron of the rimmed steel charge, because of its solvent power for hydrogen. The proper percentage may lie between 1·25% for small ingots cast in groups and 0·5% for large ingots cast singly. Silicon in the crude iron may also hold gases in solution and introduce them to the bath metal, but they will not be retained at the end by the silicon because that element must be eliminated by oxidation before a proper decarburising boil of the bath can be obtained. Crude iron evolves gas on solidifying, thus molten iron introduces some gas to the bath metal when used in the charge.

Hydrogen has been found in and extracted from cold as well as from heated and used steels by several investigators, though in widely varying amounts. Silicon steel may contain much hydrogen, but unless such steel forms part of the charge, it is unlikely that the steel scrap used will contain enough hydrogen to be troublesome. Absorption of hydrogen evidently takes place when the charge is exposed to the furnace gases. Water vapour which exists is decomposed and liberates hydrogen, which is taken into solution by the metal. Rapid melting or submerging the scrap charge in the bath may tend to minimise the amount of hydrogen absorbed.

The only agencies for the expulsion of hydrogen from the metal seem to be the boil of the bath in its variations both as to quantity and intensity, the successive temperatures of the bath, and the successive concentrations of manganese in the metal. During the boil it seems probable that other gases, in addition to carbon monoxide, leave the metal unaided, and particularly hydrogen. To facilitate the boil for this purpose calls for a proportionate amount of carbon in the bath metal, when first melted, and corresponding additions of ore. Temperature of the bath should be kept as low as possible consistent with fluidity, because high temperature favours the retention of hydrogen.

Manganese has some slight solvent power for carbon monoxide as well as for hydrogen and nitrogen in the bath metal, therefore it may work the retention of hydrogen, both by quieting the boil and by its solvent power for that gas. For either or both of these reasons it should not be contained in more than a certain allowable proportion at the end, at least, of a rimming steel heat. Silicon in the bath metal does not act like manganese in retaining the gases even though its solvent power over them is far greater, because carbon cannot be oxidised and so cause boil until any silicon which may be present in the metal is practically all oxidised and so eliminated and its solvent power destroyed.

In making killed or partly killed steel aluminium is the most effective of the solvents to prevent escape of skinhole or other gas in the ingot. Silicon and titanium have similar though much weaker power. In such steels a moderate excess of either of the three works no appreciable harm. In rimming steel, however, neither of these solvents may be present in more than minute allowable amount lest the evolution of gas in the mould be unduly checked as noted. Manganese has also in a mild degree some solubility for the gases, for which reason the finished steel in the mould should not contain more than 0·4% of it. If, with over 0·3%, the steel shows any red-short tendency in the rolls, the melting furnace practice has been in some way faulty.

* "Hydrogen in Rimming Steel has adverse effect," by H. D. Hibbard, *Steel*, Vol. 90, No. 22, 1932. pp. 25-8.

Reviews of Current Literature.

American Society for Testing Materials.

Index to Proceedings. Vols. 26–30.

THIS Index covers the *Proceedings* of the A.S.T.M. issued during the years 1926 to 1930. Committee reports have been indexed in two ways : first, each committee report is indexed under the subject designated in its title, at which place a synopsis of each report is given ; second, the subjects covered in these reports, including sub-committee reports and all appendices, are indexed separately under appropriate key words. The specification, methods of test, recommended practices, and definitions of terms are also indexed under the principal subjects covered by the standard. Papers also have been fully indexed under appropriate key words relating to their context. The arrangement has not been restricted to the words in the titles, but each paper has been indexed under a number of subjects to which it applies in order to facilitate the search for information. Attention is also directed to appropriate cross-references to other subjects that are related to the topic first consulted, where additional information might be found.

In an addition to a complete subject index it includes an author index, and it will be of real help to engineers, scientists, research workers, bibliographers, and all who desire information in many fields and who wish to ascertain whether the many papers and reports presented at A.S.T.M. annual meetings, during the period which the index covers, refer to materials, etc., on which they are seeking data.

Published by the American Society for Testing Materials. 1315, Spruce Street, Philadelphia, Pa., U.S.A.

Chemical Analysis of Iron and Steel.

IN view of the large number of works dealing with the chemical analysis of iron and steel it might be thought tha another work on the subject would be unnecessary, but the quality of matter given in this volume, together with its comprehensiveness, will ensure for it a place of considerable importance amongst technical literature dealing with ferrous materials. The authors have given rapid n ethods that are applicable to routine analyses, as well as methods that must be used to obtain the highest accuracy.

The work is divided into five main sections. The first section, which is divided into seven chapters, deals with apparatus and reagents ; qualitative tests of steels and separation of iron from accompanying elements ; special operations, which include the Jones reductor, the removal of ammonium salts, and the destruction of organic matter in solutions ; volumetric analysis, and standard samples. The second section includes the whole range of the constituents found in iron and steel, and considerable detailed information is given regarding each element. The vacuum fusion and the hydrogen reduction methods for the determination of oxygen contents are given in the third section. Considerable attention has been given to residue analysis methods for the determination of oxides and oxide inclusions, as well as methods for the determination of hydrogen and nitrogen, and those interested will find this section of considerable value. Methods for dealing with

ferro-alloys are considered in the fourth section, methods for the analysis of ores, limestones, fluorspar, refractories, slag, moulding sands, and coal and coke are given in the fifth section.

The authors' aim has been to describe in detail the various methods of analysis, and they have kept in mind the increasing demand for speed in providing accurate analyses. They appreciate that the degree of accuracy is dependent on the work in hand, and have given a selection of methods that are as simple and rapid as circumstances warrant and consistent with experience. In the majority of instances the methods have been tried out by the authors in the laboratory; particularly does this apply to routine methods. In some cases methods appear to be academic, but metallurgists will appreciate the fact that some determinations are somewhat involved if correct results are necessary.

This book constitutes a very useful work of reference for metallurgists, analysts, and students, and for all who from time to time seek reliable information relating to the analysis of iron and steel. The methods are discussed in a helpful manner, and if the operator follows them carefully he should not fail to obtain satisfactory results. Figures and tables are given to simplify many of the points discussed, and a feature of the work is the help given to the experimenter who desires further information, by numerous references to other sources of information which should adequately cover the requirements of the metallurgical chemist. The book is well prepared and its production is admirable.

By G. E. F. Lundell, J. I. Hoffman, and H. A. Bright. Published by Messrs. Chapman and Hall, 11, Henrietta Street, London, W.C. 2. Price, 42s. net.

Foundrywork and Metallurgy.

THE first four volumes of this comprehensive work were reviewed in the April issue of this journal. The fifth and sixth volumes have now been published, and these maintain in a high degree the quality of information given in the preceding volumes. It would, of course, be distinctly unfair to expect a full treatise on any of the subjects discussed, as each volume averages about 240 pages, but the condensed information they contain gives these volumes a wide field of usefulness not only to apprentices and young journeymen, but to engineering and foundry students, engineers, and departmental executives, who need information regarding castings.

Volume V. embraces sections on steel-foundry practice, malleable castings, aluminium-alloy castings, and die castings. The principles underlying the work in the steel foundry and the chief difficulties encountered in the production of sound castings are admirably stated. Both whiteheart and blackheart malleable cast iron are discussed in the section dealing with malleable castings; the effect of impurities in the iron on the resultant castings, as well as alloy additions, is given considerable attention and the importance of the annealing process is emphasised. A noteworthy addition to this section is a consideration of the inspection and tests of malleable castings. The production of light-alloy castings has been recently attended by remarkable metallurgical developments, chiefly in the great improvement which can be obtained by special treatment in casting, or by subsequent ageing or heat-treatment. This section though brief is informative. Some interesting information is given in the section dealing with die-casting, particularly on white metals and the lighter alloys, but, unfortunately, little information is given regarding aluminium-bronze die-castings and their production, for which no doubt lack of space is responsible.

The concluding volume deals with centrifugal casting, special casting production, cast-iron specifications and testing, and alloy cast irons. This volume is not the least in interest and practical importance, and the whole series can be recommended with confidence, not only to those immediately connected with the foundry industry, but to all who are in any way associated with the use or production of castings.

Edited by R. I. Rolfe, F.I.C. Published by Sir Isaac Pitman and Sons, Ltd., Kingsway, London, W.C. 2. Vols. V. and VI. Price, 6s. each net.

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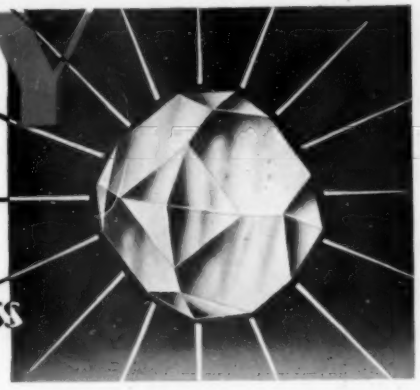

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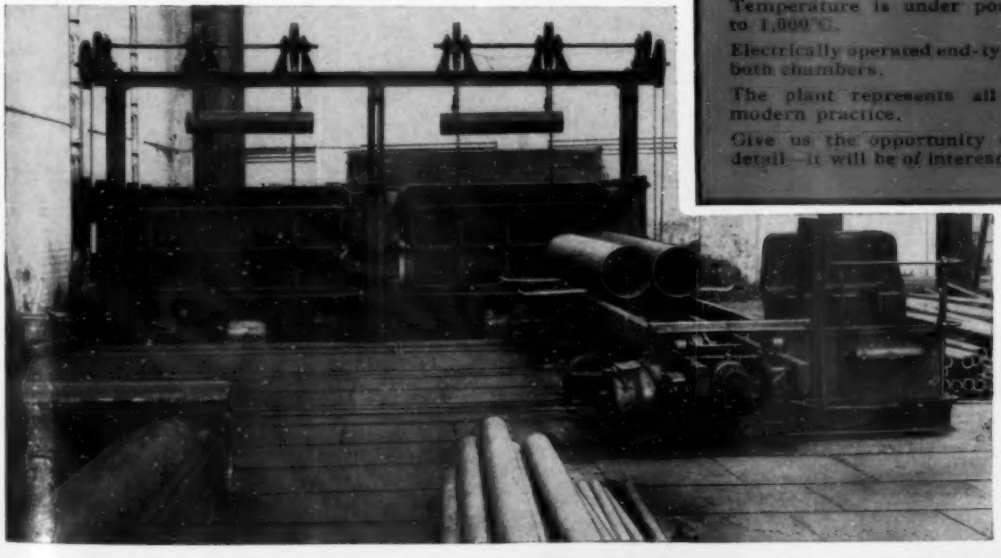

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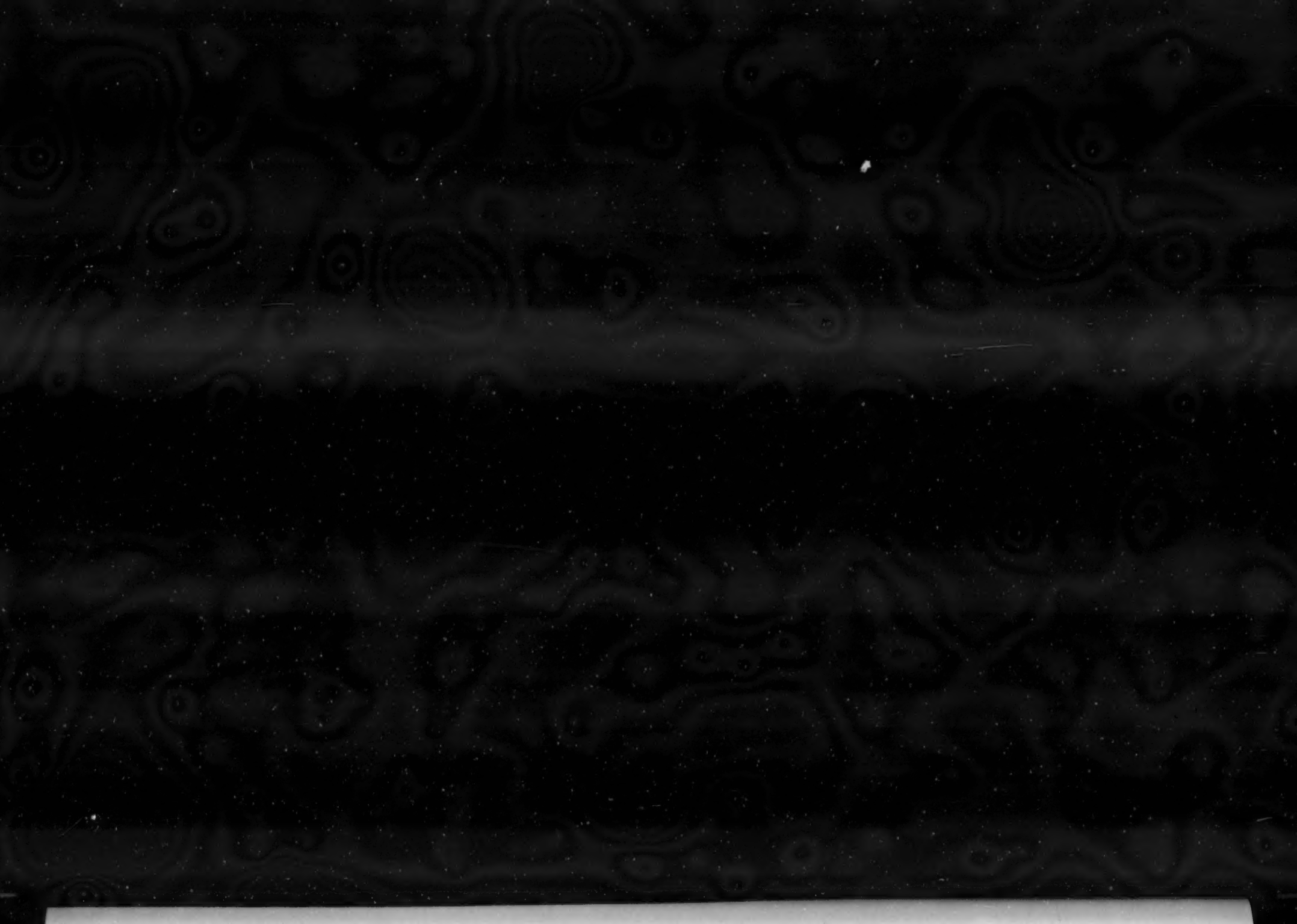
Rods	27	0	0
Battery Plates		—	

* McKechnie Brothers, Ltd., quoted June 9. † C. Clifford & Son, Ltd., quoted June 9. ‡ Murex Limited, quoted June 9

Subject to Market fluctuations. Buyers are advised to send inquiries for current prices.

§ Prices quoted June 9, ex warehouse.